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On VIEWS and GUIDES for THE ELECTRICAL ENGINEER

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This book is dedicated

TO THE MEMORIES OF

B. G. LAMME

and

A. R. STEVENSON, JR.

INTRODUCTION

This book is arranged in two sections - the first called Orientation in Electrical Engineering, and the second, Working Procedures for the Engineer. The purpose of the whole is to place in one volume material not normally presented in a single course of formal study, but material which we believe should prove of value in the general education of young engineers.

J. F. Calvert
W. J. King

March 1, 1948

ACKNOWLEDGMENTS

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J. F. C.

PRELIMINARY REMARKS

A sense of orientation should be most helpful to each man setting forth upon his professional career. In the few pages to follow, possibly a modicum of perspective may be gained on three great areas of study and activity. I am concerned with the technical phases of engineering, the liberal studies, and the professional societies. In these three each must travel to gain wisdom and experience and to leave marks for others to follow.

J. F. C.

March 1, 1948.

6-30-54 Gift Engg.

SECTION I

ORIENTATION IN ELECTRICAL ENGINEERING

Chapter

I. The Work of the Electrical Engineer

.... *J. F. Calvert*

II. Some Values for Engineers in Liberal Studies

.... *J. F. Calvert*

III. Engineers and Their Professional Societies

.... *J. F. Calvert*

CHAPTER ONE

THE WORK OF THE ELECTRICAL ENGINEER

I. ENGINEERING

Engineering has been variously described as a profession, a means of livelihood, a science, an art, and a business. It is all of these, yet it should be considered primarily as a profession. It is the profession in which men find ways to apply the known principles of the physical sciences for the general good of society. Upon graduation from college a man may start as an apprentice or a junior engineer, and later in life he may be in charge of part or all of an engineering organization. But wherever he is, the engineer expects improvement and change. He hopes to contribute his share to the new developments and particularly to their uses. He tries to find new things to do and better ways to do old jobs.

The real engineer spends much of his effort on the study of new procedures. He must learn about those contributed to the profession by others*, consider what he may add, and weigh the advantages of change. The engineer usually measures the desirability of change in terms of the probable gains in economic values. Thus, some common questions which he must answer are whether a change will save life, health, money, man hours, or materials. In certain instances he should weigh carefully the probable effects of change upon the welfare of various groups of society.

For his individual and rather creative thinking, the engineer expects, and usually gets, a reasonably good financial return. Figures assembled prior to World War II showed that on the average he fared at least as well as other college graduates with a comparable number of years invested in training. More recent events have made clearer than ever the value of, and need for, well-trained engineers.

To qualify as a professional man, one must be trained in many supporting fields. As in law and medicine, so in engineering, only through knowledge of basic principles and well-established disciplines of reasoning can a man expect to cope with the tens of thousands of problems which are to be encountered within the span of one professional life.

An electrical engineer is simply one who has specialized somewhat more than others of his profession in the basic theories and useful applications of electricity. Some of the fields of study which support his work are shown below:

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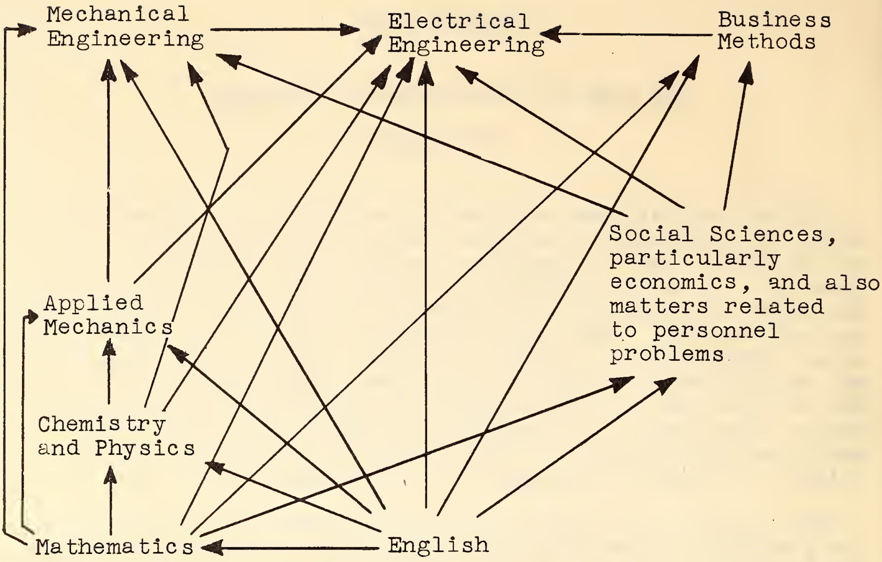
* Knowledge of scientific, engineering, and organizational advances is made the property of all who can understand it through meetings and publications of the engineering societies. These are discussed further in the chapter on Engineers and their Professional Societies.



II. SOME REMARKS REGARDING CONCEPTS

The study of physics gives to the engineer basic ideas concerning matter, energy, and radiation. There was a time when it seemed practicable to hold these as separate concepts. Matter or material, whether it was visible or invisible, resembled in our thinking such things as "mecanno" sets, the waves on a pond, the flow of water, and various discrete particles like small balls or grains of sand. To particles of matter were attributed special though somewhat mysterious powers, such as attraction and repulsion, to explain observed force and energy relations. The rigorous logic of mathematics was invoked to state carefully the rules of operation or "laws", and extremely ingenious methods were devised for testing the validity of these laws. In recent decades it has become increasingly difficult, if not impossible, to introduce into the theory units or devices, mechanical in character, which could be used to explain all the known observations. Matter and energy are no longer completely different concepts in nuclear physics. That there should be a release of energy with a corresponding reduction in mass is probably the most upsetting idea which has come into our recent thinking about physical things. By merely asking if what the physicists propound represents "truth and reality", we find ourselves moving into the realm of philosophy. It may be better to conclude that the physicists are always developing a system of logic which they intend to hold consistent within itself. Our observations of natural phenomena lead us to believe that usually one set of initial conditions leads to a single set of results. The search for consistency and truth might then be regarded as the effort of the mind to adapt itself to its environment. It is the engineer's province to apply knowledge and, therefore, he should know as much as he can of this system of logic. He can use it in his daily work and through it he can predict with considerable accuracy what trends his work may take in the years to come.

The more mechanized theories which were developed in physics prior to the turn of this century have served as the bases for much work in physics and for most engineering up to the present time, and they will be employed in a vast realm of future effort. We think of discrete particles such as positively and negatively charged ions, of electrons, etc. At other times we may make use of the analogous configurations exhibited by magnetic fields, electrostatic fields, heat flow, and the flow of water. The discrete particle concept may lead to the use of probability theory and number theory. The flow idea, when expressed mathematically, calls for continuous and single valued functions such as those of the calculus and differential equations. Not always in engineering is it possible to resort to the rigor of mathematical treatment, but usually it is necessary to have a basic understanding of the thinking done in various mathematical areas in order to acquire proper judgment for the treatment of many practical enginnering problems.

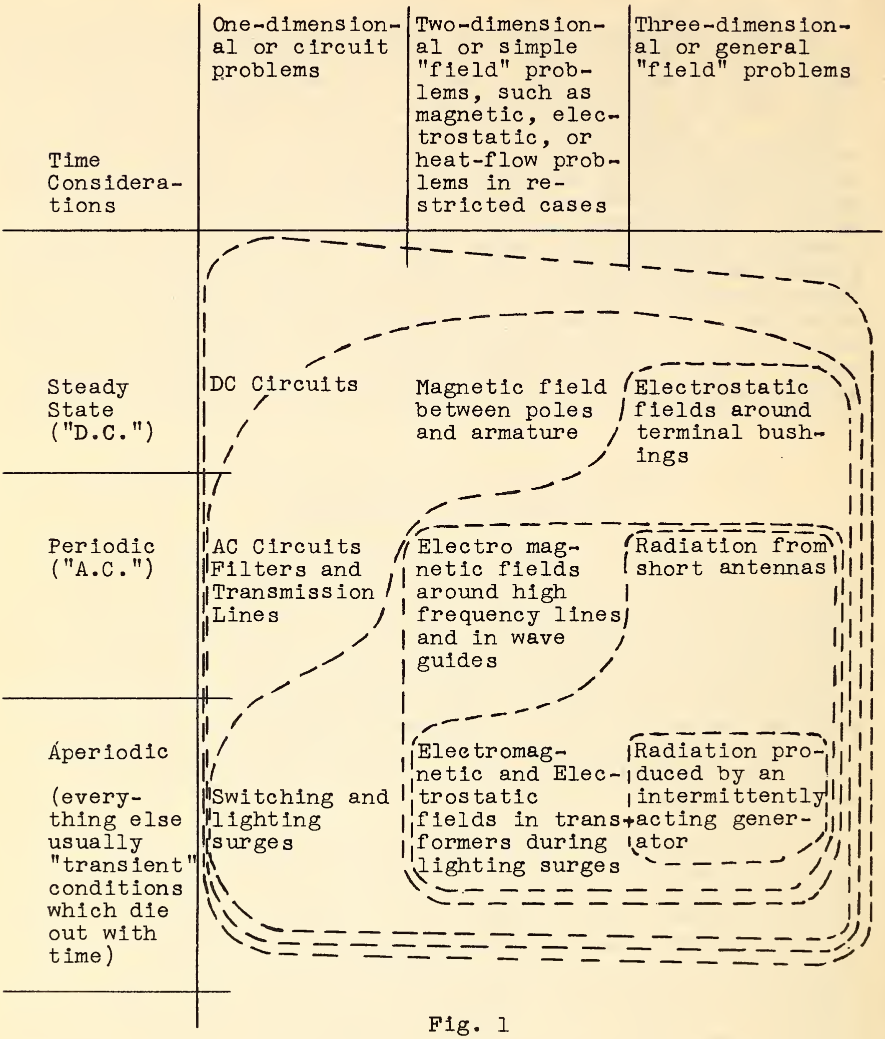
III. CLASSIFICATION OF SOME THEORETICAL PROBLEMS IN ELECTRICAL ENGINEERING

Much of electrical engineering deals with continuous functions in space and time, such as those related to the flow of electricity and heat, and to the form and propagation of electric and magnetic fields. In Fig. 1, a classification of these space-time problems is given with a few brief examples. While it is not necessarily true of the examples listed, nevertheless the difficulty generally varies with the type of problem, increasing as one proceeds from left to right and from top to bottom. Thus there is a sort of hill of difficulty, the approximate contours of which are shown by the dotted lines on the figure.

At the lower levels rigorous mathematics has been applied with great success. This applies primarily to one-dimensional flow or circuit problems and to certain two and three-dimensional problems where the physical boundaries are quite simple. At the intermediate levels graphical, and consequently less accurate, procedures have been employed to some extent. The latter are particularly applicable to steady-state, two-dimensional fields. At the higher levels also, mathematics has been used where the physical boundaries are simple, but in many instances boundaries are complex and we must rely upon experimental methods.

In most of the preceding discussion of Fig. 1 not only have continuous single-valued functions been in mind, but also constant parameters. Thus in circuit problems we usually assume constant resistances, capacitances and inductances, even though these be approximations. From these we usually evolve, subsequently, rigorous treatments of complex situations, knowing that approximations were placed in the initial assumptions.

A Classification of Problems in Electrical Engineering Involving Continuous Functions



Time Considerations	One-dimensional or circuit problems	Two-dimensional or simple "field" problems, such as magnetic, electrostatic, or heat-flow problems in restricted cases	Three-dimensional or general "field" problems
Steady State ("D.C.")	DC Circuits	Magnetic field between poles and armature	Electrostatic fields around terminal bushings
Periodic ("A.C.")	AC Circuits Filters and Transmission Lines	Electro magnetic fields around high frequency lines and in wave guides	Radiation from short antennas
Aperiodic (everything else usually "transient" conditions which die out with time)	Switching and lighting surges	Electromagnetic and Electrostatic fields in transformers during lighting surges	Radiation produced by an intermittently acting generator

Fig. 1

	Frequency		Wavelength		Quantum Energy Ergs
			CM	English Units	
	0		Infinity	Infinity	0
Electric Power	-10-	Cycles	-3×10^{9}	- - - - - - -	-6.5×10^{-26}
	-60-	Cycles	-5×10^{8}	-3120 miles	
	-100-	Cycles	-3×10^{8}	-1865 miles	-6.5×10^{-25}
(Sound)* Induction Heating	-1000-	Cycles	-3×10^{7}	-186.5 miles	-6.5×10^{-24}
	-10-	Kilocycles	-3×10^{6}	-186.6 miles	-6.5×10^{-23}
Long Radio Frequency	-100-	Kilocycles	-3×10^{5}	-1.8 miles-	-6.5×10^{-22}
	-1000-	Kilocycles	-3×10^{4}	-984 feet	-6.5×10^{-21}
Short	-10-	Megacycles	-3×10^{3}	-98.4 feet-	-6.5×10^{-20}
	100-	Megacycles	-3×10^{2}	-9.8 feet	-6.5×10^{-19}
Microwaves (Radar)	-1000-	Megacycles	-30	-11.8 inches	-6.5×10^{-18}
	-10000-	Megacycles	-3-	-1.18 inches	-6.5×10^{-17}
Heat	-10^{12}		-3×10^{-2}	-0.01 inches	-6.5×10^{-15}
Light	-10^{14}		-3×10^{-4}	- - - - - - -	-6.5×10^{-13}
Ultraviolet	-10^{16}	Cycles	-3×10^{-6}	- - - - - - -	-6.5×10^{-11}
Xrays	-10^{18}	Cycles	-3×10^{-8}	- - - - - - -	-6.5×10^{-9}
Gamma rays	-10^{20}		-3×10^{-10}	- - - - - - -	-6.5×10^{-7}
Cosmic rays	-10^{22}		-3×10^{-12}	- - - - - - -	-6.5×10^{-5}
	10^{24}		3×10^{-14}		6.5×10^{-3}

Fig. 2

The electromagnetic frequency spectrum showing the relationship of frequency, wavelength, and quantum energy. The different types of energy are shown in the approximate positions: Their boundaries overlap, however, and are by no means as well defined as indicated here. *Sound, although not an electromagnetic phenomenon, is included to show the frequency relationship. One reason for the great interest in cosmic rays is the size of their quanta---some ten thousand billion, billion times greater than quanta of power-frequency radiation and even a billion times larger than light quanta. Such energy may be useful in atom smashing.**

** These data appeared in the paper, "From Sixty Cycles to Super-Frequencies", J. E. Hill, Westinghouse Engineer, September, 1946.

Mathematics is the most rigorous and reliable form of logic for the treatment of physical problems and is of immeasurable value in engineering, particularly in electrical engineering and applied mechanics. In the past, however, there have been two important limitations. Usually, formal mathematical procedures will give you exact answers with as many significant figures as you like (here the assumptions impose the limits of reliability) or it will afford you no satisfactory answer at all. These procedures can fail in one of several ways. You may be able to get a statement of the problem in an accurate form (as is often done in differential equations) but get no further, because an analytical treatment which will yield a solution to your specific problem is as yet unknown. (Certain developments in applied mechanics modify this somewhat.*) At this point you generally choose one of several alternatives: (1) "simplify" the assumptions; i.e., choose another problem which you think is sufficiently similar to the real one and so choose it that an analytical solution can be found, (2) try to develop a step-by-step numerical solution, (3) run a test, (4) see if some computing machine, such as the differential analyzer or other device, can be successfully employed, or (5) guess and hope, relying upon "engineering experience" (Perhaps the last is only a polite name for a carefully developed intuition, yet it is a sort of reality.) Field problems may be expressed in partial differential equation form. These yield general solutions in the form of known types of arbitrary functions, but it may become impossible to arrange a sum or series of such functions to fit the boundary conditions. Finally, problems involving variable parameters are perhaps the most difficult of all, and frequently are not amenable to analytical treatment. Thus the relation between the flux density and the magnetizing ampere turns per inch for a laminated iron core reactor may introduce difficult analytical problems if this device is one element of several in an electrical circuit to which is applied a varying voltage.

Through countless centuries of development, the mind-nervous system combination has become surprisingly good at solving difficult problems in space and time. Witness the prowess of certain men in ballistics as demonstrated by a good archer, a forward passer in football, a juggler, or a duck hunter. But, unfortunately, we can make only very limited use in engineering of these particular powers of analysis. And despite these natural abilities we have made little progress toward the development of a mathematical or symbolic logic which would gain much in simplicity by a moderate but limited sacrifice in accuracy.** The most promising approach today to the adequate treatment of physical problems too difficult for analytical methods is through the development of elaborate computing machines. In this expanding field electrical engineering techniques hold a preeminent position.

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* Bibliographical reference 2, 3, 4.

** The nearest analytical approaches seem to be dimensional analysis, certain work mentioned in bibliography 2, 3, 4, and the freehand drawing of fields to solve Laplace's and Poisson's equations where the boundary conditions are specified.

The foregoing discussion shows a classification of theoretical studies according to space and time considerations. Another way of looking at electrical engineering problems is in terms of the frequencies in the electromagnetic spectrum shown in Fig. 2. From this entire range of frequencies only visible light can affect the eye and thus pass through this window to the mind. From this we may realize two things: (1) why we have had to develop such a vast array of equipment in order to cause events whose primary disturbances occur in other parts of the spectrum to produce secondary effects in the visible range which we can control and interpret; and (2) in some measure, why such difficulty has been experienced in building a consistent theory and system of logic to explain the unseen phenomena.

IV. DESIRED ENGINEERING RESULTS

Thus far we have seen, though briefly, only the foundations and a few of the tools of a profession. Let us look now to some of the things which the electrical engineer wants to do, or wants to do better:

1. Furnish accurately controlled power---sometimes in tens of thousands of horsepower---
    - (a) transport this power easily to its place of use,
    - (b) use this power in transportation equipment,
    - (c) weld parts together---metals, ceramics, and organic plastics.

2. Transmit intelligence with almost the speed of light---
    - (a) spoken words,
    - (b) written words and symbols,
    - (c) music,
    - (d) pictures.

3. Measure, record, and select, as indicated below:
    - (a) to select good units from bad ones in a production line,
    - (b) to record the beats of hearts so that data are obtained for medical diagnoses,
    - (c) to determine stress and strain in airplane structures, in crank shafts and in a variety of other flexing and moving parts,
    - (d) select from libraries and other storehouses of knowledge both specific and related data with greater speed and accuracy than is done today.

4. Control processes in order to---
    - (a) steer an aircraft by auto pilot,
    - (b) run steel or paper through the rolls in a mill at proper speeds either automatically or by great amplification of the power of the hand,
    - (c) bring an airplane along a prescribed path at a prescribed speed and land it safely regardless of visibility,
    - (d) automatically lay anti-aircraft guns.

5. Develop computing equipment* such as:
   (a) Electric calculators to do the four operations of arithmetic---addition, subtraction, multiplication, and division, at such speeds that one hundred thousand to one million individual steps may be done in a second. (These are digital machines.)
   (b) Network analyzers to solve problems for immensely complicated electrical power systems. (These are analogue machines.)
   (c) Differential analyzers to solve differential equations which are too elaborate or too difficult for treatment by normal analytical procedures. (These are analogue machines.)
   (d) Electron digital machines, like the "Eniac", some for special uses, and others for general utility to deal with problems in applied mathematics related to physics, chemistry, engineering, economics, etc.
   (e) Various analogue units for obtaining approximate date, which permit quick changes both in the form of the equation and in the magnitudes of the parameters, and yet give an immediate visual demonstration of the results of these changes.

6. Develop new, better, and more efficient sources of light.

7. Further the development of useful devices which deal with energy in the reaches beyond or above the visible frequencies, such as:
   (a) X-ray devices
   (b) nuclear power plants.

It is interesting to consider whether or not the electrical engineer's methods may continue or whether some may be superseded by those in other fields of endeavor.

On item 7 (b) electrical engineers may find that their greatest contributions can be made through electrical controls, though this is far from a proven limitation as yet. There has not been much outside competition offered in any of the other fields except on items 1 (b) and 1 (c) and to some extent, item 4. These latter areas will be discussed briefly.

Thus far, electrical engineers have been unable to successfully rid themselves of the "plug in cord". Hence, electric railways, street cars, and trolley busses have power brought in by wire to impel the moving vehicles. Except for trolley busses this has become completely impracticable for even limited highway transportation. At one time, battery-supplied electrically driven automobiles were on the streets. However, the battery has always been a heavy device and slow to charge; hence, it has not been feasible to carry it and to replenish it in a manner which could compete with the combination of gasoline tank and filling station. In diesel electric drives, the electrical parts provide control and a very flexible combination of gear shift and clutch, but the diesel is the prime mover and goes along in the locomotive. However, for the vast number of uses of power at fixed locations, such as factories, offices and homes, electrical devices seem to be superior to all other forms in cleanliness, ease of control, and adaptability to change of layout.

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* There are two basic types of computing machines. The digital employs discrete numbers. One of the earliest of this type was the abacus, still used in China but mentioned in the writings of Herodotus around 450 B.C. The modern adding machine is probably the best known today in the digital group. The analogue type uses lengths or other physical entities to represent the quantities entering into the calculations. Thus, with the slide rule, lengths represent the logarithms of the numbers which appear on the scales.

In the field of control, hydraulic and pneumatic devices are quite competitive and may be superior to the electrical on a power-per-pound basis. This is very important in aircrafts. For the actual control and for the transmission of power within such systems, the electrical methods are generally superior. Somewhat hybrid arrangements are likely to become the best for certain classes of control installations. Probably most of the equipment will remain electrical, and the theory and methods of analysis developed earlier in electrical engineering seem destined to remain the clearest and most satisfactory for control studies. Thus, in many control devices and in nearly all instruments, electrical parts have been, and will remain, indispensable--in fact, quite generally, the most important parts.

V. WHERE ELECTRICAL ENGINEERS WORK

Like most other engineers, the electrical engineer very rarely works for himself as may the individual practitioner in medicine, law, or dentistry. Fig. 3 shows where and on what many electrical engineers are employed. Results are achieved by the interacting efforts of the many minds applied on all major engineering undertakings. In fact, quite often electrical, mechanical, and chemical engineers, as well as other scientifically trained persons, are required at one time to work as a team on a single project. Thus, a common language and some knowledge of many fields is needed among all of the professionally trained men thus engaged. The ability to describe quickly and simply the bare essentials of a problem is a necessity. Those engaged on the purely technical problems must understand each other. Engineers in supervisory positions must be able to assimilate a great deal of information regarding all parts of the work in order to make correct decisions.

Thus, engineers usually work for engineers, and quite frequently, or perhaps most often, sell to engineers. The electrical engineer may well expect to work for a moderate-sized to large organization and probably to spend most of his days in urban areas.

Manufacturing

(a) Manufacturers of power equipment, such as:
- (1) motors,
- (2) generators,
- (3) water wheels,
- (4) transformers,
- (5) railway equipment,
- (6) switch-gear, etc.

(b) Manufacturers of measurement control, recording, and selection equipment for industrial processes.

(c) Manufacturers of electronic equipment for:
- (1) control,
- (2) radio,
- (3) telephone,
- (4) television.

Operating

(a) Utilities and other service companies, such as:
- (1) large power companies,
- (2) telephone,
- (3) telegraph,
- (4) radio,
- (5) railway organizations

(b) Variety of industrial organizations, as:
- (1) steel mills,
- (2) paper mills,
- (3) chemical plants,
- (4) cement mills,
- (5) rubber plants.

(c) Various government organizations, such as:
- (1) T.V.A.,
- (2) the Army, Navy, Air Corps,
- (3) Civil Aeronautics, etc.

Design and Consulting

(a) Firms engaged in the design and erection of power plants, steel mills, hydro-electric plants.

(b) Some individual work in electronic and control equipment.

Agents for Manufacturers Domestic and Foreign

Usually sales of special products in various locations, and sales of standard products in areas distant from the manufacturer's plant.

Teaching

Primarily in universities at undergraduate and graduate levels.

Government Research

Army, Navy, Air Corps, Bureau of Standards, etc.

Fig. 3

VI. WHAT ELECTRICAL ENGINEERS DO

If the engineering progress of the future is to compare favorably with that of the past, the engineer must maintain a professional outlook. This means his actions and recommendations should be directed primarily toward change and improvement and certainly not toward maintaining the status quo for the protection of personal interests.

Within the fields of endeavor shown in Fig. 3 there may be various types of work, among which are:

1. Research
2. Engineering Development
3. Design
4. Consulting (in a few instances and usually by older men)
5. Application Engineering
6. Testing
7. Factory Production
8. Equipment Maintenance
9. Sales
10. Personnel
11. Legal Work (usually involving formal training in patent law)
12. Advertising

VII. ENGINEERING DECISIONS

Past events have shown that by the time a graduate engineer is 40 to 45 years of age he is more likely than not to be employed partly or entirely on administrative work. Since many engineers are so engaged, it is well to observe that administrators are being paid primarily for the decisions they make regarding work done by other people and, only to a very limited extent, for direct contributions which they make to the solutions of current problems. As has been indicated earlier, one rarely makes a decision in engineering which is based on purely physical or scientific data. Nearly always there are other factors, and usually in the past these have been concerned with the relative scarcities of money, materials, or man hours. The decision on any problem worthy of mention is usually not easy--all is not black or white. The executive, however, may well set up certain priorities, and certain auxiliary standards. Thus, profit may be the number one item in his decision, but he has a number of auxiliary standards which he intends to preserve, regardless of whether he makes a profit or not on a particular job. Thus, if he produced a water wheel generator for the Hoover Dam and it were to fail, lives might be lost, his own and his company's reputation would suffer, and also the future business. As another example, he can hardly afford to jeopardize employee safety or health. Or again, he might hesitate to withdraw the benefits he was furnishing with or without contract, if these were important to employees and to employees' good will.

Fig. 4 gives some further examples of what might serve as the bases for judgment in some engineering decisions.

One item in particular in Fig. 4 seems to call for further comment. There has been much said and written pro and con concerning government projects, such as the Tennessee Valley Authority, the Missouri Valley Authority, etc., where the

SOME POSSIBLE PRIORITIES AND MINIMUM AUXILIARY STANDARDS IN ENGINEERING ECONOMY

	Private Industry	Public Utilities (Government regulated, privately owned)	Government-Installed, Owned-and-Operated Projects
In times of war	1. Man hours 2. Materials 3. Money or stored up economic values Auxiliary standards on health, reputation for patriotism, etc.	1. Sufficient continuity and quality of service to meet war needs 2. Man hours 3. Materials 4. Money Auxiliary standards on health, reputation for patriotism, etc.	1. Government standards 2. Man hours 3. Materials 4. Money or stored economic values Peacetime auxiliary standards seem to hold to a considerable extent.
In times of peace	1. Money (or profit) 2. Man hours and materials, mainly as affected by costs, except as controlled by auxiliary standards. Auxiliary standards on health, satisfactory personnel relations, and reputation of the product.	1. Money or profit 2. Maintenance of almost a perfect record for continuity and quality of service. 3. Man hours and materials, mainly as affected by costs, except as controlled by auxiliary standards. Auxiliary standards are very high on safety and health, continuity of employment, and maintenance of good public relations.	In operation much the same as for the public utility. However, the initial installation should not be primarily for the purpose of making money. Undoubtedly final decisions can become political matters, but benefit to society at large over a period of time should be almost the sole cause for expenditure. Harbors, sanitation, irrigation, and flood control are examples of possible just causes for such investments of the public's funds. Nuclear energy development is another.

Fig. 4

government has appeared to be operating almost in direct competition with privately owned central-station industries. Some have undertaken to justify such competition by claiming the costs prevailing in the government system could serve as a "yard stick" for rate-setting in the privately owned government-regulated utilities. Unless it can be shown that there were very large discrepancies in the claims of the privately owned companies which somehow could not be found by government-employed auditors and engineers, this argument seems not very strong. The same engineers and auditors would need to check what went into the calculation of the government utility costs.

This does not mean, however, that such government activities cannot be fully justified. There are from time to time certain great engineering projects that should be planned and carried through by government because private capital and private industry seem unprepared to undertake them. Top soil is something which must be preserved. It is a national resource of consequence to everyone, whether he owns the land or not. Hence flood and erosion control and reforestation are accepted as legitimate investments for public funds. Similarly, what agency other than the government will undertake the construction of immense dams, and with these, the irrigation of otherwise useless lands? If in the process of flood control or of irrigation, it is economical to develop electric power as part of the total project, then this also seems to be a justifiable undertaking to avoid the waste of potential energy. However, it does not necessarily follow that the government should then assume the normal functions of privately owned utilities. It is possible that such private enterprise should be encouraged to lease the power plants at federal or state owned dams and also to accept the responsibilities connected with the generation, transmission, distribution, and sale of the available electrical power. These are matters on which engineers should study and recommend without rancor or bias. There may not be one best procedure which can be applied throughout the country, nor one location where one procedure should remain invariable with time.

There are other fields where government expenditures will occur or may be expected because they seem to be in the interests of the general welfare. Military needs and also peace time safety seem at this time to warrant government development and control of nuclear power. Greater financial support in research is needed in this country. The latter, however, could be given further aid by government or by industry or by both, but it is needed for the good of all.

New political, social, and economic problems are being created through the applications of the physical sciences. To meet their responsibilities, the future engineers must be public-minded and alert. This flowing activity must be confined and guided so that it will not wash away the foundations of our culture, but may serve to freshen the soil of civilization from which comes strength and thus the opportunity for vision.

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CHAPTER TWO

REMARKS FOR ENGINEERS ON VALUES IN LIBERAL STUDIES

Justice Oliver Wendell Holmes said, "The mark of the master is that facts which before lay scattered in an inorganic mass, when he shoots through them the magnetic current of his thought, leap into organic order, live and bear fruit." This statement has meaning for all phases of a well-rounded professional training.

Most engineers can explain how they benefit through their scientific and technical training; they can show clearly that such studies aid them to become masters in their chosen professional work. When asked to explain the values that they see for themselves in liberal studies, they are apt to be far less concise and to present fewer concrete examples to support their principal arguments. Most of us have observed, in a general sort of way, that those who study extensively in the latter fields seem not only to acquire knowledge, but to develop a certain perspective and judgment regarding some of the past and present affairs of the world. However, it is apt to appear that unless one has time for extensive study in some specific area of learning, the work in liberal arts can offer only a smattering of knowledge in a number of rather unrelated fields of thought.

Usually the engineering student has the equivalent of about one college year or less to devote either to free electives or to some large area of study such as the humanities. Viewed in the light of what has been said up to this point, the curricular requirements in liberal arts are apt to appear to the undergraduate engineering student more as duties to be performed than as opportunities to be grasped during his period of formal and intensive college work. And, even though incorrectly, they do appear exactly so to many of the younger engineers.

The two questions I wish to discuss are: (1) What may give these liberal studies unity in the mind of the engineer, and (2) what do they offer that will be of direct benefit to him in his career? In endeavoring to answer these two questions, I shall have to touch even though lightly, upon many things in the life and education of the engineer. To establish a starting point, a comparison will be made between the work and thought of those in the physical sciences and those in other fields. On the assumption that the need for a unifying theme does exist in the conscious mind, an effort will be made to show what form this may take, and that it may be found by the individual rather than by society as a whole. There are certain working theories accepted by our own society which should be clearly understood, and important ones will be listed. There are salient data, affecting the lives of all of us, which need to be observed and considered. From these, the unifying theme, working theories, and salient data, we may see the principles upon which a general education might be based, and view a number of specific problems to which the principles should be applied. After a discussion of the foregoing I believe that it will be possible for one to see more clearly what a general education should mean in the life of the engineer who is today embarking on his professional career.

I. A PARALLEL

In today's changing world new ideas and new theories from almost every field of thought come forward for consideration, and from time to time seem literally to batter the mind for acceptance and for use. To meet intelligently problems as they appear, one needs training in both the technical and non-technical areas.

In the physical world some seek more nearly ultimate theories regarding the nature of matter and energy. Others, such as the engineers, develop working theories, relations and laws; they make observations and tabulate data on their surroundings, develop skills and judgment, and learn to apply accepted principles in various fields of endeavor. Somewhat similarly in the world of intangibles, men desire to have a unifying theme or principle. They develop working theories, make observations, develop judgment and powers of decision, and employ accepted principles and data in various general and cultural fields of thought. With this parallel between the scientific and the liberal studies in mind, we should see what the latter may mean to the engineer.

II. THE PROBLEM OF THE UNIFYING THEME

Education impinges upon almost all of the activities of man; hence, in considering its aims one soon meets age-old questions concerning the purposes of life and the significances of the conscious mind. (Conclusions, if both definite and generally accepted, would become the unifying theme in all education.) It has been chief among the purposes of religion to establish standards for human conduct and to give meaning to life itself. But religious organizations are supported by human beings. In the past some of these organizations have not always been tolerant or receptive to the changes suggested by scientific studies, and at times they have become self-perpetuating hierarchies which presumed to specify the actions, behaviors, and thoughts for all mankind. While there have been large groups who thought alike regarding theologies and philosophies, their ideas moved and changed, and at no time in this country have we reached agreements which might serve as a completely unifying set of principles. Consequently, it has been the considered judgment of our society that the state should support schools in which specific sectarian doctrines were not taught, but that the establishment of other schools through religious organizations or through private enterprise should be permitted, provided there were no infringements of individual or collective freedoms.

Reaching for a satisfactory explanation of the purposes of life by a process of reason and experiment is like trying to place your finger on a drop of mercury; though you are unable to pin it down, still you may believe full well in its shining existence. While we seem unable to express a universally acceptable unifying theme for life itself and hence for education, each, if he chooses, may see much the same thing from his own individual point of view. Thus the unifying theme may be the belief, or faith, or ideals which a man lives by. It may be developed through the church, through education, through informal discussions, and through quiet thought. Yet it is an individual sort of thing, and it may unfold and grow for each man throughout his lifetime if only he has the desire and the will to make it so.

III. WORKING THEORIES, RELATIONS AND LAWS

The difficulties encountered in seeking a universally acceptable unifying theme are concerned rather more with somewhat unproven beliefs which are quite theological in character, than with historically supported principles of ethics. The latter can give a solid foundation for working relations. Christian ethics in content, and to some extent in origin, have much in common with those of other faiths. The working principles for western civilization have come to us not only from the Bible, but also from the ancient Greeks*, and possibly to some extent from the early Teutonic tribes. In recent times they have been modified by the advances made in science.

In this country the Declaration of Independence was written to express many of these principles. The laws of the land, particularly the Bill of Rights, were prepared to give them support. In a free society such as ours we hold among our working theories:**

1. The right to know
   --free schools, free speech, and free press,

2. The right to believe
   --free religions, and free philosophies,

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* For centuries they were preserved for us primarily by the church.

** Acknowledgments 2.

3. The right to differ
   --free speech, free press, and fair protection for minority groups,

4. The right to be an individual
   --freedom to love one's own, the right to marry and to establish family life, the privilege of seeking employment, and the right to seek unregimented recreation,

5. A government by the consent of the governed and provided with means for peaceful change
   --free elections with secret ballot, and these at guaranteed intervals; open discussions in and out of assemblies with details available to the electorate; and systems which provide for decisions by a majority vote,

6. The privilege and, in fact, if our own rights may be threatened, the obligation to defend the rights of free men anywhere
   --the Monroe Doctrine, participation in two world wars, some action with the League of Nations, and more recently on the floor of the United Nations, bear witness to belief in this principle.

These working theories are based on the findings of centuries of human experience. It is presumed by us that they are to be altered very slowly, and hence, in the main, will provide stable guides for individual and collective action throughout periods of time much greater in length than that of one man's life. (While these have been our beliefs, let us not lose sight of the fact that they have been challenged. They were not those of all whom this country opposed either in peace or war during the first half of the 20th Century.)

IV. OBSERVATIONS CONCERNING WORLD SURROUNDINGS

It is necessary for us to face salient data regarding our present-day surroundings. These, though possibly transitory as historical events, are powerful in their effects. Many are relatively recent developments:*

1. We live in world surroundings which are undergoing rapid and even accelerated changes in the physical environment which affect many people, their human relations to one another, and their social and political institutions.

2. The causes of many of these changes have been the developments made in the physical sciences and in technology, and these developments will continue to effect even more rapid changes in the future.

3. The free time available to many persons for study in biology, medicine, psychology, and the social sciences (and possibly art), also will lead to other great, and maybe for a time, accelerating changes.

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* Acknowledgments 2.

V. GENERAL EDUCATION

Thus far I have attempted to employ a parallel between studies in the physical sciences and other less technical fields of education. For each field the problem of the unifying theme seems shrouded in much the same mist of uncertainty; each has its own working theories, and each its recorded observations. These may be given interpretation regarding the individual and his liberal education.

It seems safe to state that the educated man should develop certain attitudes of mind, and important among these are:

1. An expectation of change,
2. Tolerance yet vigilance regarding longer range issues,
3. An ability to judge and to weigh, and
4. A certain degree of vision to the future regarding both the probable and the desirable conditions in his world.

All this implies a certain breadth of knowledge and an orderly arrangement of factual data.

How then may a liberal education contribute to this development? In sum:

1. It should be suitable to the times in which we live,
2. It should provide guides and systems of measures which are calibrated into history in order to furnish standards of judgment of the present and possible future, and
3. It should furnish certain practices in judgment, in evaluation, and in decision.

To give further meaning to these last statements, we should consider them, even though very briefly, in terms of certain fields of study.

History

One may list in outline form certain factors which have been of great importance in history:*

1. The struggle for food.
   How to get food with less effort, and at times how to get it at all, have been impelling forces throughout history.
2. The struggle for other natural resources.
   Many today take for granted paved roads, fine homes, city buildings, heat, light, and power. Yet there has been a continual struggle for resources, and as history progressed the desires have expanded. At first men sought for hunting grounds and rivers in which to fish; and

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* Acknowledgments 3.

later, in approximate sequence, for grazing lands, farm lands, harbors, copper, tin, iron, coal, oil, and today for deposits of uranium.

3. The importance of power from nature.
For centuries there were well-stated ethical grounds for the abolition of slavery, but not often were these pressed by many of the most high in society or in government. The development of cheap and readily applicable power made slavery uneconomical among more advanced peoples; and with the coming of power, this blight on the races of man began to vanish from the earth. (Yet even today, there are areas of the world, where, in effect, slavery still exists.)

4. The very recent recognition of productive work as desirable for every individual.
Although this concept is now commonly accepted and sometimes exalted, especially in the United States, this is a new idea in history. Labor was made a curse by the excessive effort required to tear a living from the earth and by the very long period in which slavery prevailed. It would appear that the decree "In the sweat of thy brow thou shalt gain thy daily bread" was taken by the early Hebrews to be a punishment rather than a blessing.

The value of mental effort has long been appreciated, but not particularly so when applied to physical things. Until relatively recent times engineering was elevated to a position hardly worthy of mention. Certainly the ancient records show far more of the rulers, the generals, the writers, the religious leaders and the philosophers, than they do of the designers and of the builders of great ships, temples, roads, and aqueducts.

5. The effects of science and invention.
Little time is given even today in the study of science, and practically none in engineering, to the biographies of those who contributed so richly to developments in these areas. Studies of this character may yield not only interesting background but clues to the ways in which progress has occurred.

It may aid short-range perspective to consider certain events which have occurred within the working life span of a man retiring from industry today. Radium was discovered not long before this man was first employed, and during his productive years he became aware of the following, each of which was vitally influenced by the work of science and of engineering:

(a) Radium was put to use;
(b) Radio, radar, and induction heating were developed;
(c) The United States changed from a debtor to a creditor nation and thence to a great debtor to itself;
(d) The Sherman Anti-Trust Laws were introduced;
(e) The Wagner Labor Act became law and acquired various meanings through administrative and legal interpretations. It is being modified today by new laws and their interpretations;

(f) The great empires of Kaiser Wilhelm, Hitler, and Mussolini, and the ruling class of Japan all expanded and collapsed through war;

(g) In 1905 Albert Einstein published the first of his works, which some believe will lead to influences in man's physical world as great as did the discoveries of ways to produce fire.

(h) The number of "first class military powers" has decreased with successive wars from 1914 through 1945 in some ratios approximated by 8:6:3.

From the above hasty observations it is hoped that some hints may be gained of the sort of things one might seek to understand through studies in the field of history.

Labor

It is of much importance to the young engineer to learn what he can of the present hopes and aspirations of labor, of its leaders, and of its rank and file. To this end it is of value to study the history of the labor movement. It appears that, at the start, the industrial revolution was not a boon to the men, women, and children who worked with their hands. They were at the mercy of those who had property rights, and who in turn were slow to develop anything approximating an enlightened outlook. *The Reverend Joseph Townsend, a popular clergyman, wrote in 1785,

"It seems to be a law of nature that the poor should be to a certain degree improvident,--they are reconciled to the meanest occupations--and to the most hazardous pursuits.--When hunger is either felt or feared, the desire of obtaining bread will quietly dispose the mind to undergo the greatest hardships, and will sweeten the severest labour."

Another, a Dr. Patrick Colquhoun, said:

"Without a large proportion of poverty, there could be no riches, since riches are the offspring of labour, while labour can exist only in a state of poverty."

As an indication that, with the passing of many years, there was improvement in outlook, we note that in 1842 Col. Perronet Thompson said in writing of Bolton, Lancashire, in the heart of the English cotton mill area,

"Anything like the squalid misery, the slow, mouldering, putrefying death by which the weak and feeble of the working classes are perishing here, it never befell my eyes to behold. --They sit down with Oriental submission as if it was God and not the landlord who was laying his hand upon them."

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* Acknowledgments 4.

It took both laws and action by labor unions to stem the downward trends resulting from the so-called "competition" of the individual worker with large blocks of wealth.

Though important as background, all this is far different from the greater industries and from the immense and powerful labor unions of today. While it clearly appears that protection for the individual worker is needed, so also may consideration be needed for the stockholder and for management, and most certainly for the many individuals in the general public, who may be only remotely concerned with any specific industrial disagreement. Back of the Sherman Anti-Trust laws seems to have been the theory that to have real competition and to reap benefits from it, there must be many teams to play the game, and to some extent those of comparable power should be scheduled in one league. Does something of this sort apply to competition between labor and management, and if so, what about the general public? Labor relations are to remain of great importance in the work of the engineer for many years to come and they warrant his continuing study.

Economics

Economic theories may seem rather dry and abstract at times, but their existence has contributed to some rather cataclysmic upheavels in Europe and throughout the world during this century. In the study of economics it used to be possible for the beginner to believe that, within the capitalistic system, business cycles were almost like cycles of the sun--repetitive, unalterable, and inevitable. It seems now, at least, that they do not appear to be entirely repetitive; they have gained in amplitude of late. Actually this economic system is man-wide, even if not designed, and insofar as nature is concerned it is probably influenced most by the simple cupidity of human beings. Yet a system of reasonably free enterprise actuated by the profit motive has, despite its shortcomings, much to commend it. No other seems to have been better in getting the most brains and the most concentrated effort applied to the millions of problems of business and of human needs. Presumably, we should be capable of inserting some "damping", or better still, "negative feed back", to reduce oscillations and to increase stability without impairing a good and going system. Certainly the problems of the cycles of plenty and want are of paramount importance to us all, and it is to be hoped that engineers may contribute something to the solution of these difficulties which, inadvertently, they have helped to create.

Law

Law to the layman, and particularly to the engineer, seems slow and much encumbered. One wonders why it need take as long to settle an estate as to build a Hoover Dam. In effect, we seem to have law by judges, law by jury, law by executive order, and law by statute. Yet justice, though slow, seems relatively sure, and touched by mercy. It has behind it centuries of careful refining. Law and government in this country are intended to safe-guard the rights of the individuals, and are not for the glorification of the state. An engineer should know something of law's theories and procedures. Also, he should be interested to learn what is being done so that law may mark the way for the orderly progress of industry along the modern highway of engineering.

One might continue to comment briefly on a vast number of other fields of study which can be of interest and value to the engineer. A few of these would be psychology, sociology, foreign languages, English literature, and fine arts. Study in any of these may do things to a man. The great literatures conserve for us the best and greatest thoughts of the past. Fine arts have contributed much to, and taken much from, designs in engineering. Perhaps in the future one of the greatest fields of common interest between the arts and engineering may occur in city planning, even though there are others in product design and, for the electrical engineer, in sound and in illumination.

VI. WHAT THE FUTURE MAY HOLD

What the young engineer who is graduating today may see in his working years, one may only guess, but some of the possibilities are these:

1. Great expansions in the use of nuclear energy for biological and medical applications, and for the development of physical power.

2. The continued shrinking of the world's surface as measured in terms of time and ease of travel.

3. The "opening up" of undeveloped land areas to the north in Canada, Alaska, and Russia, to the southeast in Asia and Malaya, and in various parts of Africa. (We are able to conquer indoor climate, to some extent to combat cold out-of-doors, and are reducing the dangers of disease. Provided potential wealth in these areas warrants it, this expansion of "civilization" will take place. However, we still need to find a way to carry a cool climate around with us out-of-doors somewhat as we can carry a warm one by wearing more clothes!)

4. Great advances in biology, psychology, and medicine which will reduce the percentage of fatalities from diseases of the middle-age and old. This, it is generally assumed, will have marked influence on our social life. Advances in these fields also may yield great results in the treatment of mental illnesses.

5. Efforts--possibly successful--to get devices and even men almost beyond the gravitational pull of the earth.

6. A continuing movement toward world-government--either by choice or force or both. War, like slavery, has long been with the human race, but war has become increasingly destructive and devastating. One may well consider a quotation from the preamble to the constitution of the

United Nations Educational, Scientific, and Cultural Organization (UNESCO) which reads as follows:

> "that since wars begin in the minds of men, it is in the minds of men that the defences of peace must be constructed;...."

Or perhaps one may ponder a much older quotation:

> "And God said (to Solomon), 'Ask what I shall give thee'." And Solomon said, "'Give thy servant an understanding heart....'" (I Kings 3-5b, 9a)

In the past, through force of arms, we have preserved our way of life, and given ourselves a chance for lasting peace. This opportunity we need to respect and to cherish, but peace cannot come through victory in war alone. Somehow there must be developed trust and mutual understanding among the peoples of the world.

From a consideration of the theories, working principles, and the changing world surroundings, it should be clear that education must be a continuing process throughout life, and that the development of attitudes and balanced judgment are as important as are the acquisitions of facts and knowledge.

Possibly through the changes and developments suggested above, and certainly through many yet undreamed of, the engineer who is starting his career today will see the tremendous impact of science upon both the personal lives and upon the political surroundings of men. It is the effects of these impacts which will be of greatest importance to all. Many of them will be directly applied by the engineer. If he desires to do his job intelligently, he may well start early his general education and expand upon it in parallel with his engineering studies, as a student, as a practicing engineer, and as an active citizen.

The world today is divided by conflicting theories regarding the desirable ways of life. In this nation we have our own working principles which have come down to us from the Greeks and from the early Christian era. They are those held by free men and with us they are essentially Christian principles. They have been refined through hundreds of years of trial and have gained both in strength and flexibility. They offer ways for change without coercion, or violence, or human degradation. They warrant the active support of every free man, with his family, in the civil life of his community, in his business, in his state and national governments, and in his relations to the world at large. Careful thought, vigilance, and active citizenship are the prices both of freedom and of progress. As never before, the engineer, if he is to be fully a man, must carry out not only his duties within his profession, but must give intelligently of his time and his substance to maintain and to strengthen the working principles which are his way of life. And this he may gracefully give in the light of the many who gave life itself.

ACKNOWLEDGMENTS

1. All items of this list, except 5, are given about as they were presented by Dr. M. A. Tuve in the address at the time of the laying of the cornerstone for the new Naval Ordnance Laboratory, at White Oaks, Maryland, in the summer of 1946.
2. See bibliography reference 1, page 313.
3. For many of the items in this list, see bibliography reference 1, Ch. II.
4. Bibliography reference 1, Ch. V, pages 115-116.

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CHAPTER THREE

ENGINEERS AND THEIR PROFESSIONAL SOCIETIES

I. PROFESSIONAL STATUS

In order to understand the work of the professional societies, first we need an answer to the question, "What are the characteristics of a profession?" This question is not new. One common approach to the answer is made by taking the older professions of medicine and law as the primary standards and comparing all else with these. The method is sound, if carefully applied, but a common fallacy is to assume that the rather individual work done by the country doctor and the small-town lawyer is the primary requisite for professional status. This assumption soon leads to either unwarranted restrictions or to outright inconsistencies. A brief reflection shows that, while many doctors and lawyers in urban areas also conduct their work as single individuals, many others are employed as members of practicing groups. Before going further into the problem, let us note that some engineers practice individually but most are employed in organizations. Furthermore, while the doctor and lawyer very commonly serve the layman, the engineer is more likely to deal with other engineers.

At this point I hope we are inclined toward the idea that neither the singleness of action of the practitioneer, nor the degree of professional training possessed by the recipient of the services, can be basic to a satisfactory definition of professional status. I believe it will be found that whether it be in medicine, law or engineering, the characteristics of the work which set professional men apart as definable groups within the general society may be listed in terms of the true motives, purposes and responsibilities, and even to some extent, in terms of the privileges granted to their kind. If there is to be a profession, the members individually and collectively should (1) be motivated to a great degree by the desire to render service either to individuals or to the public, this desire not to be overshadowed by that for personal gain, (2) assume the responsibility for the advancement at a high intellectual level of specialized knowledge which is made available through written and spoken words to all who may understand and benefit, and (3) establish and maintain high ethical standards not only in dealings among professional men, but also in dealings with the general public, in order that the best interests of the public may be served.

In return, the professional group may expect, and usually receives, acknowledgment and support from the state through licensing laws which impose certain qualifications upon a man's right to practice professionally where the public interest is directly involved. Yet it must be kept in mind that the sole justifiable purpose of such laws is to protect the public interest. A professional group may expect such aid through law not just because of the special skills of its members and the ability of the group to discipline its individual members, but because the legislators expect these skills and disciplines to be so applied that reliable services at fair costs will be rendered to the public at all times. Qualities and costs of the services must remain comparable with those which might be obtained by any other conceivable procedure*

II. THE PURPOSE AND WORK OF THE PROFESSIONAL SOCIETIES

The foregoing has been written not only to show the character of professional work, but to indicate that organization among professional men is a necessity.

One organization of primary importance to electrical men is the American Institute of Electrical Engineers. In 1884 a few leaders among those interested in the practical applications of electricity founded this society, the purposes of which are "the advancement of the theory and practice of electrical engineering and the maintenance of high professional standards among its members". The society today has a membership of about 30,000, grouped in Sections and Student Branches throughout most of North America. However, there are two other great and vigorous societies interested in electrical work - the Institute of Radio Engineers (IRE), and the Illuminating Engineering Society (IES). The IRE, filling new and important needs, has grown rapidly, and embraces today a membership approaching that of the AIEE.

Through the meetings and publications of these three great societies, the knowledge of the science and art of electrical engineering is made available to all. Were it not for the sort of work they do in advancing the known art, the present-day benefits of electrical applications would be far less and enjoyed by fewer people, the average quality of the men attracted to such professional work probably would be low, and there would be fewer opportunities for satisfying work in the electrical field.

Besides providing for the spread of new knowledge, the professional societies have established and maintained fairly rigid, yet growing, standards for equipment and for technical procedures. Some appreciation of the effects of these standards may be gained by contrasting developments in certain technical and semi-technical fields. As examples, the standards in electrical and in mechanical engineering, established through the professional societies, have been sufficiently rigorous to result in safety and good equipment; yet, they have been so flexible that within a span of about ten years (though not the same span in every case) each of the following took place:

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* For a more detailed discussion of professional status the comprehensive paper "Toward the Making of a Profession" by Dr. W. E. Wickenden, is suggested. In it are carefully defined the attributes of both individual and group professional status. See Bib. Ref. 1.

The largest turbine generator in existence was once 25,000, later 205,000 kva; hydrogen cooling for turbine generators was developed and commercial units were delivered to central station engineers for use; steam pressures and temperatures for turbines in commercial use went up from a few hundred pounds per square inch and a few hundred degrees fahrenheit to around 1,200 to 1,500 pounds pressure and 900 to 1,000 degrees; radio became a world-wide business; radar grew from a few laboratory devices to commercial equipment (though this was primarily a war and not a peace time development). Compare these developments with the almost negligible changes in building practices for homes which have come into general use throughout this country during the past several decades. The use of power tools, extensive prefabrication of parts, and the general introduction of quantity production methods, which would seem to be the desirable ways to reduce costs in this field, have not been extensively introduced. Admittedly the great variety of personal tastes among the buyers have had retarding effects on such development. But is it not safe to assume that, in a large part, the building codes and general business practices have not been very conducive to developments, while the standards of the AIEE, ASME, and similar societies, brought into their fields of work bold engineering backed by venturesome capital, the combination of which led to great engineering advances?

III. THE NEED FOR GREATER UNITY

The major engineering societies, such as the AIEE, IRE, ASME and others, have faithfully carried out their purposes since their founding; but in recent years many members have wondered if this is enough to meet the present and future needs of the individual members, or of the profession.

During World War II there seemed to be no central organization which could speak with assurance for all engineers on professional matters. Engineers in the United States are represented by around fifty to one hundred technical societies. In contrast, we may observe that there is just one American Medical Association to serve the overall interest of the physicians, even though there are also organizations for specialists.

Some have contended that the engineer is just a delightful individualist and that nothing much can be done about it. It is at least true that he is an individualist but so is the physician. Nevertheless, there probably are as many men in the engineering societies who are expert in large-scale organizational matters as there are in almost any other professional group in the country. The need, yet lack of organization among engineers, as a professional group, presents an anachronous situation which seems to call more for action than for passive observation.

There are three movements afoot today which point to the consolidation of engineering organizations in order to satisfy their common interests.

1. In various large cities there are Technical Societies Councils and the Engineers' Clubs which have been growing in strength. Of the two, the Engineers' Clubs show somewhat more uniformity in membership requirements and in the interests of the individual members. However, each type of organization seems to serve well the common interests of the engineers insofar as local matters are concerned.

2. State licensing, or registration of professional engineers, has led to the establishment of the National Society of Professional Engineers. The standards for membership in this organization are high and likely will become higher as licensing requirements take more effect on the quality of those becoming registered. This organization eventually might carry on its rolls a high percentage of the engineers. Conceivably, it could become a very strong centralizing force, yet it alone is most unlikely to assume the responsibilities for the specialized publications, meetings, and standards that are now provided for by the AIEE, IRE, IES, ASME and other similar societies.

3. Several possible programs have been under careful study by the Planning Committee of the AIEE, which are aimed at the establishment of a single society with various technical subdivisions for those interested in electrical, mechanical, chemical, or other branches of engineering. These possible programs have been submitted for comment to thousands of engineers and have been forged and tempered by this process.

Yet, this is neither the first nor possibly the last organized effort to achieve greater coordination among the engineers. Strange as it may sound to the student, the establishment of an effective single or overriding society may take more broadmindedness than exists among the older engineers today! And this is so, even though in the minds of many there is the conviction that we need a coordinating body. If faculties and students also are of this mind, then the best place to lay the groundwork is in the colleges. The operation of joint student engineering councils with representatives from the AIEE, IRE, ASME, ASCE, etc., could be used to bring in special speakers and to promote many other matters of interest where unity on campus is needed. Such joint action would develop a sense of common professional interest among all these men who will in time become the future engineers of the country.

And this brings us to a discussion of student technical societies.

IV. THE STUDENT BRANCHES

Student branches have been established in the colleges for many years by the AIEE, ASME, ASCE and others of the older professional societies. Paid-up student membership usually carries with it a subscription to the national magazine. Recognizing the community of interest among engineers, the AIEE recently provided for the establishment, upon approval of the Board of Directors of the Society, joint student branches to which may belong student members of various technical societies such as the IRE, ASME and others of comparable standing.

Through the branch, students can learn a good deal of the operating procedures of the societies and have the opportunity of meeting many of the leading older members of the profession. The nearby sections are anxious to cooperate in every way possible with the branches. The AIEE has prepared, and made easily available, a list of possible Section-Branch cooperative activities, but it is most glad to receive further suggestions for such work at any time. Student paper contests are being reestablished and in various areas special prizes are offered by the Sections and/or the Districts for best student papers.

Immediate and long-range problems which will be faced by engineers should come up for discussion at student meetings. The engineers, if they are to properly fill their places in our society, will have to take in increasingly active part in civic and national affairs. More of them will be expected to serve as advisers and consultants concerning government projects. A greater number of the more able should hold public office than do today. Besides the many interesting technical meetings which they will hold, it would behoove the young electrical engineers through their student branches to secure on their programs from the liberal arts colleges, from industry, and from government, men who can speak authoritatively on subjects in history, sociology, political science, philosophy, on labor and management problems, and on national affairs.

To fully round out his professional training a student should be an active member in his student branch. He should take a part in planning its programs and its papers and appear on its open forum discussions.

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PRELIMINARY REMARKS

A man has much to learn through professional experience, but collected and classified information on problems commonly faced by many engineers should serve the individual as possible guides to progress. In this Section we endeavor to show some of the normally successful procedures for securing employment, to present accepted principles of conduct for the employee and the employer in American industries, and to describe ways by which the individual may enhance his abilities for creative work in the development of new devices.

W. J. K.
J. F. C.

March 1, 1948.

SECTION II

WORKING PROCEDURES FOR THE ENGINEER

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CHAPTER ONE

SEEKING ENGINEERING EMPLOYMENT - WHEN AND HOW

I. GRADUATION FROM STUDENT TO ENGINEER

During a war and for some time thereafter finding an engineering position is a relatively easy matter. In certain economic periods, jobs have been thrust at the man who, if he were free to accept, could almost take his pick. At other times this has not been true and it probably will not remain so indefinitely. Always there is the problem of really getting into the company and the job where one can get the greatest personal satisfaction out of accomplishment. This article is written on the basis that, during certain periods of our economic history, getting a job is a problem, and that, in any period, getting the right job is always a task in itself. There are certain techniques, fairly well proven by past experience, which the engineer may use in studying employment possibilities and in seeking a position. It is intended to review these methods primarily from the point of view of the young college graduate who is ready to make his start in the engineering world.

Today a very large percentage of the young engineers will find their work with some industrial organization, and those who do should always keep in mind that the purpose of any legitimate business, operating under our social and economic system, is to render service for a reasonable profit. When the young engineer first goes into a company, it may be arranged that he spend part, or even all, of his time for some months in studying the organization, its methods, and products. Certain companies make it possible for a man to pursue further academic work. Whether or not any of these facilities are afforded, a man must continue to study throughout his years of useful employment. Sometimes this may be done through formal classroom work, but more often it will be accomplished by the man giving systematic and careful thought to the existing and future problems before him. However, when a man is employed in industry, he passes through the apprenticeship stage in a period of time which varies from a few weeks to one or two years, depending upon the arrangements of the company with which he is affiliated. Thereafter, his major problem is to fit into his company in such a way as to be of the most value to the organization. He must place the student viewpoint in a decidedly secondary position and assume the role of the engineer. The most valuable "experience" becomes that which he gains through responsibility.

II. WHAT THE EMPLOYER WANTS

Modern industry, from research to sales, involves many personal contacts and business relations. Strange as it may seem, the research man or the designer today will have many problems of selling within his own organization. A large company is in reality a large community with vastly complicated interrelations of interests and considerable overlapping of responsibilities. Consequently, a new idea, whether an invention, a design or a shop process, usually requires explaining to many before the interested people will accept it for practical use. From this it is apparent that the industrial employer needs "all-round" men.

The employer and personnel man in a large company has here a difficult problem: How is he going to pick such men? Obviously, he can find no simple formula, yet the right men must be hired. The young man should not only be gauged for his present all-round qualities, but also for his potential abilities, since the employer in many cases is more interested in the type of man he will have five, ten, and fifteen years hence, than he is in what he is getting at the start. The young engineer's record to date must be the employer's guide. The personnel man might well list the things he is interested in finding, and many a one does just that. Such a list would probably contain the following, or the equivalents:

*1. Character--integrity, responsibility, resourcefulness, initiative

2. Health--stamina, endurance, emotional stability

3. Judgment (in its broader interpretations)--common sense, scientific attitude, perspective

4. Efficiency--thoroughness, accuracy, industry, ability to plan and to carry out plans

5. Understanding of men--cooperativeness, ability to speak well but to listen carefully, ability to "lean over backwards" in giving the other fellow his due credit

6. Knowledge of the fundamentals of engineering science

7. Techniques of engineering practice, and business experience

It is believed that the items of the above list are arranged about in their proper order of importance. However, an employer would, no doubt, make certain definite reservations for their use. Let us suppose that he undertook to grade, roughly, a man on each of these points according to some standards existing in his mind as a result of his industrial experience. He would have to

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* With the exception of Item #2 which has been inserted above, this list is taken from a paper by Professor L. O. Stewart of Iowa State College; and originally from a well-known study on engineering education made in 1916 by C. R. Mann of the Carnegie Foundation, based on replies received from some 7,000 engineers. Health has been inserted in the above list because of the almost universal and unquestionable rightful emphasis placed upon it by present-day employers of engineers.

increase the penalty very rapidly as any one rating went down. Thus, to take probably the most extreme example, any very serious question regarding a man's integrity would rule the candidate out of consideration even though the rating the man received on Items #2 through #7 were very good. The same would be true to a lesser degree regarding the other items. This further emphasizes the importance of a well-rounded training.

III. SEEKING EMPLOYMENT

While there is no universal rule in this regard, it is a fact that very few men are employed for engineering work without a personal interview. If the company sends a personnel man to the college, the time and place for the interview is more or less prearranged and the young engineer has no great part to play in getting himself before the employer. If the young engineer is either in college, or out of college, he may find it necessary or desirable to arrange for certain interviews himself. His problem will vary, depending upon whether he is in college, just out, a few years out, or quite a number of years out. However, in any case he can do several things to make the contact where necessary, and to have the interview take place under conditions most favorable to him. He needs to know as much as possible about the company at the time of the interview, and he should be able to present his case in clear and concise form.

A. STUDY OF THE INDUSTRY.

In learning something about the company where you hope to secure employment, you should study their product, their past history, if possible, and their financial rating. Of course, you can talk to people who you think might know something of the particular company, but a certain general knowledge of your industry is a desirable guide. In reading through the technical literature and the more popular magazines, you should glance through the advertising with an eye to the engineering products, who make them, and why they are made as they are. When you go through the city newspaper, you will be informed from time to time of both the troubles and controversies, as well as the scientific and commercial developments of the industry. Read all of these with some interest and allow yourself time to wonder why and how these things have occurred as they have. The catalogs of manufacturers and distributors will tell you much about their products. You can learn something of the company's financial standing from Moody's Manual of Investment, and from Bradstreet's Journal of Trade, Finance and Public Economy. Thomas's Register of American Manufacturers furnishes lists of companies according to businesses, and also a list arranged alphabetically according to the names of the companies. There are industrial directories prepared by many cities, counties, and states. The public libraries are yours for the using and you can secure much valuable aid from the librarians. If you happen to know people who are the customers of a company, you can consider yourself acquainted with its friends, and probably with its most faithful critics. You can easily learn from them, without necessarily disclosing your personal interest in the company, if you prefer not to bring out your problem.

There are one or two further sources of information which deserve consideration. In some large companies you may find in the outer office of the employment department a fair collection of descriptive literature concerning the company's work and organization. If the company maintains an office where visitors come to go through the plant, you might find similar information there prior to an interview.

Thus far, we seem to have thought in terms of very large industries with personnel men and all of the other subdivisions which might be expected in such organizations. However, there are many small companies to be considered, and this brings to mind the perennial question of whether it is better to work for a small or a large company. There is no answer to this, any more than there is an answer to what an executive or a personnel man is going to be like. The companies, like these men, operate more or less according to certain business standards, but there are good ones and a few bad ones; and like individuals, the companies seem to have personalities which appreciably influence their individual methods of procedure.

The large companies will usually offer you a better opportunity to learn the business through a training course. Some people argue that there is greater tenure and security with a large concern. Others advise that the opportunities for advancement are greater with the small company. You cannot generalize and you can only judge the individual opportunities for yourself, but actions speak louder than words, and if you know anything of the company's history as it was affected by its present management, you may gain some idea of its future performance. What a business may have in store for its employees in general, and for you in particular, is something that no one can answer with assurance, but something which you must be prepared to study. As a rule, you cannot go to another man and ask him to solve your problem for you. In the first place, he probably cannot do it; in the second place, you will do better to seek guidance or advice where you need it but primarily to hold counsel with yourself. You can accumulate a great deal of evidence through reading and general discussions as mentioned above. Besides the financial standing, what you can learn of the diversity of the company's services and products, of its present and future usefulness, and the probable severity of its competition from the services and products of other companies, are items for your serious consideration. So much for obtaining information. You need to weigh it in making your own judgments, and to employ some discretion in its use. Unless the prospective employer brings it up, you will probably gain very little by asking him any direct questions regarding the company's finances, and it would hardly be appropriate to inquire too pointedly into his labor policies, particularly if he is undergoing difficulty. In other words, do not put the interviewer "on the spot." Nor is it advisable to make blunt inquiries regarding his research laboratories if he has no research facilities whatever. These examples may seem somewhat far-fetched, yet they are cases which have actually occurred at student interviews and have occurred as a result either of ignorance or of very little forethought on the part of the candidate for the job. Yet you can often get much of this information once he starts telling about his organization. It is better to ask how he accomplishes something. Generally speaking, he will tell you.

B. PERSONAL RECORD

So far, we have considered certain information you should like to know concerning the industries and how to search for the data. The employer or personnel man is going to want certain information about you which he can look over, preferably before, and possibly during and after your interview. As a student engineer, you are learning to write engineering reports; as a practicing engineer you will be called upon to write more and better engineering reports. You have this same kind of problem here. You will find it impractical to write a satisfactory report concerning yourself in an ordinary letter. The best method seems to be to design or arrange a personal record. When an employer comes to the university, the school can place this before him and there is no problem. If you are arranging your own interview, it is desirable to have a copy of this personal record reach the employer before your interview. More will be said later about getting it before the employer.

The preparation of data about yourself will serve more than one purpose.

1. It will probably be the first time you have ever summarized your own work in a clear-cut fashion and therefore the experience should be of some value to you, personally.

2. It will afford you the opportunity of planning the best possible arrangement for presenting this information in a clear and dignified manner. You can put considerable thought and individuality into this job and thereby learn how to do this sort of thing, if necessary, when you are out of college, and how to judge another man's data if at some later date you are doing the employing.

3. It gives you the material to present to a possible employer in the manner best suited to your needs.

This personal record should be typed, and generally it is best to arrange it in outline form so that each item can be easily found and understood. It might be from one to five pages in length. For a man just out of college, usually one page will be enough. The paper should be good and preferably of standard size (8½ x 11). Adequate margins should be allowed all around, and particularly on the left-hand side. It is well if the arrangement is your own. Certain of the items which should appear in the personal record are as follows:

a. Photograph. A personal photograph, showing head and shoulders only, should accompany your application. This should be not larger than 2½" x 3". It must be placed where it will not be creased in folding for mailing. One good location for it is in the upper right-hand corner of the sheet. If you do not have a good photograph, either secure a good one if time permits or else omit it altogether.

b. Personal Facts. These include your name, address, telephone number, age, date and place of birth, your citizenship, state of your health, height, weight, single or married, and if married, whether you have children or other dependents. Possibly, the nationality of your parents and also your father's occupation should be included. The date this personal record is made should appear in some suitable place on the sheet.

c. Education. The high school training may be mentioned if desired. Your college degree, school, and date of graduation must be mentioned. Advanced degrees, if any, should be similarly recorded, and any other school work or industrial training courses which you have taken ought to be mentioned. It is usually desirable for a man just graduating from college to list the one or two courses he enjoyed the most, or that he considers most valuable. A complete list of courses is not advisable.

d. Affiliations. Membership in honorary and professional societies, and church membership or preference should be given here.

e. Activities. The man leaving college should list here student activities such as class offices and memberships in various societies, the college band, fraternities, participation in athletics, and possibly hobbies. If you have designed and built any model aircrafts, engines, dynamos, radios, or other engineering devices, these might be mentioned as hobbies under or included as a separate item in your data. You should not include projects which were thought of but which were not carried through.

f. Experience. While you want to make this information brief and concise, be sure to make it complete. If you are writing this personal record at the time you are just graduating from college, include all jobs you have held before and during your college career, whether these jobs are engineering in character or not. Anything pertaining to sales, construction, customer relations, and engineering are of particular interest.

If you have been in the armed services be sure to list concisely your complete record but avoid the use of abbreviations and terms not generally understood by non-military personnel. Make very clear your training, experience, and your responsibilities while in service.

Quite often special or unusual business experiences may be found, to your surprise, to be of considerable interest to some employer.

It is also desirable to state the percentage of your college expenses earned in total or in each year.

g. References. It is almost a universal custom to give references. Probably three to five are sufficient. If you are just out of college, two or three of these should be faculty members who have had you in their classes. Former employers, hometown business men or your superiors in the armed services may each make good references. (Needless to say, you should never use a relative's name, not even an in-law's.) It is not necessary to ask permission of these people to use their names, although that is one way to notify them, and it is a good idea to let them know in such a way that they will recall immediately the details of their experiences with you.

During and following a war it is easy to get a job offer. This is not always the case, however. Should you feel that a number of copies of your personal record are needed, you might arrange to have these turned out by one of the companies doing photographic reproduction work. While this record should be your own, you should feel free to consult with the faculty or anyone you believe can give you good advice on its preparation. When you have been out of college long enough to have held an engineering job, you probably will not want to use a reproduced, but rather a typed, personal record. The number of copies needed likely will be less. Possibly you will choose to omit or to abbreviate further the facts concerned with your high school record. Certainly you should include a record of your engineering work since graduation. If, at a later date, your experience has become extensive, you will have to resort to some tabulating scheme to cover your practical work and will probably require two to five pages to cover your complete record. Nevertheless, the length should be held down as much as is consistent with accuracy and completeness. In such a tabulation, you should give not only your position and the work for which you were held responsible, but also the name and title of your immediate superior at the time you were on that particular assignment. While you are not going to be job-hunting often, nevertheless you may find it desirable to keep a reasonably up-to-date record on file with the University. Thus, when inquiries come in for men from time to time, this record may bring to the minds of the people back at the school the fact that you are the man who could well fill that better position.

C. LETTERS OF APPLICATION.

In case it is necessary to make your application for the job by mail, then your letter of application is to a certain extent one of transmittal for the personal record, in that it will accompany the record and can be reasonably brief. However, in it you can make your application for a position with this particular company. (Whether or not you definitely apply in this letter may depend on your previous contact with the company.) Before considering the content of the letter, you should keep in mind certain other matters. Frankly, your letter must be in accordance with standard business practice if it is to be worth the paper it is written on. The letter should be typed on 8½" x 11" business paper (your own and no other's). It should have the usual margins, centering on the page, etc., used by a skilled secretary. The mechanics of the letter should be perfect. (If you are troubled, as some are, don't forget that matter of spelling!) You would do well to consult a good standard book on business letter writing, and if you question your own work at the typewriter, you should enlist the services of an expert on this instrument.

The content of the letter is another matter. First, be sure you have the correct title of the man to whom you are writing. List the necessary items you wish to discuss before you actually write the letter. Perhaps you have been advised to write to this company, or you have heard of a vacancy; or it may be that neither of these is the case, but you are interested in getting into a certain line of work done by their organization. Whatever may be your reason for writing, it is a point which might serve to open the letter. Perhaps something in your experience may seem to fit in well with the work done by the company and you may care to mention this if it really applies. It is well to remember the fairly general rule stated earlier, that in normal times if there is no interview, there is usually no job. Therefore, you are apt to be designing this letter to secure an interview with the man to whom you write. If such an interview is totally impractical at the moment, you may know that the man to whom you write is to be within traveling distance for you at a later date. Possibly you may have reason to believe there will be a representative of the company in your part of the country whom you might see at a certain date.

Obviously, there are too many possible avenues along which your approach may have traveled for iron-clad recommendations to be made. However, your letter must be thought out and then not marred by poor typing if it is to stand out from the others received. Yet it should contain a clear, concise statement of facts which can lead the employer on from your personal record to an interview and to a job.

Concerning the foregoing discussion of the personal record and the letter of application, you have probably visualized the complete preparation of the first before you approach an employer, and probably the second. However, you may be notified of an opening rather unexpectedly. If it is possible for you to reach the necessary place for an interview, then you should be sure of the name and title of the man you hope to see, and get in touch with him immediately to see if you can secure an interview at a time convenient to him. If the man is located in the city where you are, use the telephone. If there still is time before the interview, you can mail him your personal record with a brief letter of transmittal to the effect that he may care to look over your record before he sees you. If there is not time between your phone call and interview, you should, if practicable, hand him a copy of your personal record at the interview.

D. INTERVIEWS AND FOLLOW-UPS.

The important fundamentals in an interview are well known and it may seem trite to mention them, yet some of these are often overlooked by the candidate for a job. Certain of the more important items are:

1. Be on time for the interview if you want the job.

2. Good bearing--stand well, sit well (without slouching), yet be at ease. Do not make any of the obviously simple errors such as entering the man's office with your hat on, chewing gum, or smoking.

3. Good grooming--your suit should have been pressed, your clothes, shoes, fingernails, shave, haircut, etc., should be up to the mark. Dress conservatively in a business suit with nothing which might be considered an ostentatious display of college jewelry or other personal adornments.

4. Good manner and alertness.

    (a) The interview usually begins when you enter the room, in that the interviewer is gaining his first and very important impressions of you. After walking in and shaking hands with the interviewer, you might ask if he would care to have your record before him while talking with you, and hand him a copy of your personal record. If you do this, it would probably be best to say nothing of any other such record you have mailed him unless he mentions that he has one. In this case, you are simply bringing your copy in for convenience. If the interview occurs at the college, you should not need to hand him a copy of your personal record. He should have just received one and you can check on this with the faculty before your interview.

    (b) You should be prepared to answer questions on why you want to work with this company and what kind of work particularly interests you.

    (c) You should allow the interviewer full opportunity to steer the conversation and should answer all questions directly and honestly without any attempt to bluff.

(d) If the interviewer does not keep the conversation going, but leaves it up to you, you should be prepared to carry it on in the direction of your interests. There are probably certain general questions regarding the work done by his company, and also some questions concerning the departmental arrangements and responsibilities which you may care to ask. The market for the company's products, the living conditions, starting salaries, policies regarding salary advances, may include other points which you would like to hear discussed. Perhaps other pertinent questions concerning his company may have arisen in your mind as a result of your reading. You may find the opportunity for explaining your interest in his company and mentioning one or two points in your experience and training, if he has asked no questions regarding these.

5. Termination of the interview--when you find the interview approaching its close, it is a little better for you to terminate it than to leave it entirely up to him. If there was nothing said definitely to the contrary, you might express clearly the hope that you may find employment with his organization provided you care to go with his company.

6. Follow-up

   (a) If this interview is one which does not occur at the college between you and a visiting personnel man, then it would be well about one day after this to write the man to whom you talked. In this letter you should thank him for the interview, and you may express your interest in work with his company, and the hope for a further interview either with him or with someone else at a later date, or for a position with his company. (Of course, what you write here depends upon what has been said in your initial interview and what you want.)

   (b) If you received encouragement but no definite conclusion has been reached, you may find it advisable to follow up in about a week or ten days with a telephone call or a brief personal call to inquire if any changes had transpired which would increase the probability of an opening for you with the company. If you are out of town, you could write concerning this. Remember that all letters, like the letter of application, should be typed, should be carefully thought out, and should be mechanically perfect.

IV. AFTER GRADUATION

There are several questions which seem to arise in the minds of quite a number of graduates either before or shortly after graduation. Certain of these will be commented on:

A. SHOULD A MAN TAKE GRADUATE WORK UPON COMPLETION OF HIS FOUR-YEAR COURSE, LATER, OR NOT AT ALL?

The tendency toward graduate work is increasing. Not always, but in general, it is inadvisable for a man with less than a "B" average to undertake such work. (Many graduate schools will not accept less for entrance.) He should certainly have been in the upper half of his class (scholastically speaking). The man should not come back aimlessly, merely to carry on more school work, but should come back for a definite purpose. He should know what type of work he is particularly interested in and feel that he should learn more about it. It is not necessary for him to obtain practical experience to know his own mind on such a subject. He may reach quite definite and valid conclusions during his undergraduate days concerning graduate study. Circumstances arising in connection with his job may lead him toward or away from such study, if his decision is to be made sometime after he received his first degree.

It seems that too few of our men receiving the BS degree in engineering are continuing with advanced study in the graduate school. This has been due in part to the industrial men who are recruiting students, each of whom is very anxious to bring back the best, in part occasionally to weak-kneed advice from faculty, and in part to the fact that the students are tired of studying and are anxious to accomplish something in both an engineering and in a financial way. There are needs now as never before in research, development, design, and many phases of application engineering for more men with advanced training, and these needs will increase as time goes on. The theory that the young man can go back later if he wants to is usually only a mirage. He marries, he develops opportunities of value in the company which he cannot relinquish, and the busy years of increasing home and industrial responsibilities roll on.

B. IS IT A GOOD OR BAD IDEA TO MOVE ABOUT FROM COMPANY TO COMPANY PURELY FOR THE PURPOSE OF SECURING VARIED EXPERIENCE?

The so-called "rolling stone" idea is one sometimes advocated. It seems to come more from the "old timers" and probably more from the older civil engineers who, at the completion of one job, were drawn to another. This is purely conjecture, but definitely in the more stable industries today the idea of moving about to obtain experience is not generally regarded with favor. The employers feel that the man who moves for this reason is not interested in the job, and that he will no sooner become useful than he will move on to another company. He will not carry his share of the work while there, but will step out and leave just another headache for the employer. In many large companies it is possible to advance within the organization as vacancies, expansions, and developments occur. Such advancement is not necessarily in a straight line within your own department, but may lead into another department where your special experience is particularly useful. Occasionally a customer of your company may need a man and you may have an opportunity to move into a better job with him. In general, you should move when the new job will afford increased responsibility and opportunity for usefulness. Such a change should carry increased compensation, or at least a commitment to that effect if the job you are leaving is a satisfactory one.

If you are with a company which you are certain is mis-managed, and which you are convinced will continue to be, you probably cannot give the organization your best work. In this case, you would do well to look elsewhere for a position, while still holding the present one. Assume next that you are in a company or a part of a company where you feel that you have been pocketed, and where you see no future for yourself over a period of several years, and from which position you find it is not politic to seek another position in the organization. Be sure in your own mind that you are not being impetuous. Imagine it is some other man who is in your place. Then, if you are sure of your conclusions, look at your bank account, hold your position, do your job well, but also look for another job. As a general rule, it is not a good idea to quit one job to find another.

C. SHOULD A MAN ASK FOR A RAISE?

During the boom years of war and postwar, employers have been inclined to wonder how long it would be before the man came back for more. Times have not always been so, and for younger men some suggestions on reasonable procedures in more "normal" times may not be entirely amiss. When you first go to work, you will probably, through ordinary conversations, have learned something of the "normal" progress of raises when "times" are reasonably good. In other words, you can roughly gauge your progress as compared with others. If you find you have been passed over for a time, you should talk it over with your superior. That is, you do not discuss other men's increases, but you do very definitely call to the attention of your superior your belief that you are worth more than you are getting. (Use some judgment in regard to good, fair, and bad times.) If the boss doesn't think so, you should have a frank discussion to find out what you are doing that needs particular improvement. Never let such a discussion become heated or personal. Hard though it may be to do, discuss it as an abstract problem, yet see the thing through to as reasonable a conclusion as you possibly can.

D. WHAT SHOULD A MAN DO WHEN AN OUTSIDE OFFER COMES TO HIM?

This problem, like most of the others, depends upon whether or not you are working for open-minded men. If you are working for a good company (usually you are), you should have had a sufficient number of discussions on other subjects to estimate this. If your superiors are fair-minded men, you owe it to them to talk it over with them and to discuss your future with your present organization. Unless there is some most unusual cause for rush, both companies should give you a reasonable time to weigh the prospective job against the advice of your employers, provided they do not both point in the same direction for you.

In taking up such a matter, you may have to do a little thinking with respect to the person to whom you are going to talk. You are primarily responsible to the man for whom you work, yet it may be advisable to go to the manager of the department. It is usually preferable to state quietly to your immediate superior that you plan to talk to the manager rather than to ask permission. If you ask, you might be refused, and yet you know perfectly well that you should take the matter up yourself with the man who is to make any final decisions rather than have someone else do it all for you. This is a case where it would seem that you should noramlly speak personally both to your immediate superior and also to the man responsible for the payroll on which you are employed.

You may find that getting and holding a job is pretty much up to the individual--and to his luck! However, there are some things which can be done to influence your luck. First, you owe it to your company and to yourself to maintain a healthy regard for your job and for your company's interests and personnel. No doubt you will strive to become an excellent man in your particular field of work; that is essential. However, if you endeavor to be a good all-round man, have friends, acquaintances, and outside interests, you also give your luck "a break." It is a significant fact that on the average, such men go further and accomplish more than those who merely stick narrowly to their work and remain relatively unknown to their fellow workers.

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The papers of Professor A. D. Moore (University of Michigan) appearing in the H.K.N. "Bridge," publications of Professor L. O. Stewart (Iowa State College) appearing in the Iowa Engineer, as well as discussions with Professor Moore and also A. A. Kruse (formerly with Northwestern University), have been drawn on to a large extent in the preparation of this article.

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The electrical engineering professional society, Eta Kappa Nu, prepared a pamphlet shortly after the close of World War II which was entitled "About Employment of Engineers." The series of articles assembled there were reprinted from "The Bridge," which is the publication of the society. The articles listed below are among the best references available:

1. "Pointers on Seeking Employment" by Arthur D. Moore
2. "Self Analysis Is First Step In Job Seeking" by Prof. Lowell O. Stewart
3. "Job and Company Analysis" by Prof. Lowell O. Stewart
4. "The Letter of Application" by Prof. Lowell O. Stewart
5. "Staging the Interview" by Prof. Lowell O. Stewart
6. "Step Up To Success" by Prof. Lowell O. Stewart
7. "After the Discharge" by Fred H. Pumphrey
8. "The Engineer and Management" by Lee H. Hill

CHAPTER TWO

*THE UNWRITTEN LAWS OF ENGINEERING

PART I--WHAT THE BEGINNER NEEDS TO LEARN AT ONCE

Some years ago the author became very much impressed with the fact, which can be observed in any engineering organization, that the chief obstacles to the success of individual engineers or of the group comprising a unit were of a personal and administrative rather than a technical nature. It was apparent that both the author and his associates were getting into much more trouble by violating the unwritten laws of professional conduct than by committing technical sins against the well-documented laws of science. Since the former appeared to be indeed unwritten at that time, as regards any adequate and convenient text, the following "laws" were originally formulated and collected into a sort of scrapbook, to provide a set of "house rules," or a professional code, for a design-engineering section of a large manufacturing organization. Although they are admittedly fragmentary and incomplete, they are offered here for whatever they may be worth to younger men just starting their careers, and to older men who know these things perfectly well but who all too often fail to apply them in practice.

Just a few points should be emphasized: None of these "laws" is theoretical or imaginary, and however obvious and trite they may appear, their repeated violation is responsible for much of the frustration and embarrassment to which engineers everywhere are liable. In fact this paper is primarily a record, derived from direct observation over a period of seventeen years, of the experience of four engineering departments, three of them newly organized and struggling to establish themselves by the trial-and-error method. It has, however, been supplemented and confirmed by the experience of others as gathered from numerous discussions, lectures, and the literature, so that it most emphatically does not reflect the unique experience or characteristics of any one organization.

Furthermore, many of these rules are generalizations to which exceptions will occur in special circumstances. There is no thought of urging a slavish adherence to rules and red tape, for there is no substitute for judgment, and at times vigorous individual initiative is needed to cut through formalities in an emergency. But in many respects these laws are like the basic laws of society; they cannot be violated too often with impunity, notwithstanding striking exceptions in individual cases.

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In Relation to his Work

However menial and trivial your early assignments may appear, give them your best efforts. Many young engineers feel that the minor chores of a technical project are beneath their dignity and unworthy of their college training. They expect to prove their true worth in some major enterprise. Actually, the spirit and effectiveness with which you tackle your first humble tasks will very likely be carefully watched and may affect your entire career.

Occasionally a man will worry unduly about where his job is going to get him--whether it is sufficiently strategic or significant. Of course these are pertinent considerations and you would do well to take some stock of them, but by and large it is fundamentally true that if you take care of your present job well, the future will take care of itself. This is particularly so in the case of a large corporation, where executives are constantly searching for competent men to move up into more responsible positions. Success depends so largely upon personality, native ability, and vigorous, intelligent prosecution of any job that it is no exaggeration to say that your ultimate chances are much better if you do a good job on some minor detail than if you do a mediocre job as section head. Furthermore, it is also true that if you do not first make a good showing on your present job you are not likely to be given the opportunity of trying something else more to your liking.

There is always a premium upon the ability to get things done. This is a quality which may be achieved by various means under different circumstances. Specific aspects will be elaborated in some of the succeeding items. It can probably be reduced, however, to a combination of three basic characteristics, as follows:

(a) Energy, which is expressed in initiative to start things and aggressiveness to keep them moving briskly.

(b) Resourcefulness or ingenuity, i.e., the faculty for finding ways to accomplish the desired result, and

(c) Persistence (tenacity), which is the disposition to persevere in spite of difficulties, discouragement, or indifference.

This last quality is sometimes lacking in the make-up of brilliant engineers, to such an extent that their effectiveness is greatly reduced. Such dilettantes are known as "good starters but poor finishers." Or else it will be said of a man: "You can't take him too seriously; he'll be all steamed up over an idea today but tomorrow he will have dropped it and started chasing some other rainbow." Bear in mind, therefore, that it may be worth while finishing a job, if it has any merit, just for the sake of finishing it.

In carrying out a project do not wait for foremen, vendors, and others to deliver the goods; go after them and keep everlastingly after them. This is one of the first things a new man has to learn in entering a manufacturing organization. Many novices assume that it is sufficient to place the order and sit back and wait until the goods are delivered. The fact is that most jobs move in direct proportion to the amount of follow-up and expediting that is applied to them. Expediting means planning, investigating, promoting, and facilitating every step in the process. Cultivate the habit of looking immediately for some way around each obstacle encountered, some other recourse or expedient to keep the job rolling without losing momentum. There are ten-to-one differences between individuals in respect to what it takes to stop their drive when they set out to get something done.

On the other hand, the matter is occasionally overdone by overzealous individuals who make themselves obnoxious and antagonize everyone by their offensive browbeating tactics. Be careful about demanding action from another department. Too much insistence and agitation may result in more damage to a man's personal interests than could ever result from the miscarriage of the technical point involved.

Confirm your instructions and the other fellow's commitments in writing. Do not assume that the job will be done or the bargain kept just because the other fellow agreed to do it. Many people have poor memories, others are too busy, and almost everyone will take the matter a great deal more seriously if he sees it in writing. Of course there are exceptions, but at times it pays to mark a third party for a copy of the memo, as a witness.

When sent out on any complaint or other assignment, stick with it and see it through to a successful finish. All too often a young engineer from the home office will leave a job half done or poorly done in order to catch a train or keep some other engagement. Wire the boss that you've got to stay over to clean up the job. Neither he nor the customer will like it if another man had to be sent out later to finish it up.

Avoid the very appearance of vacillation. One of the gravest indictments of an engineer is to say: "His opinion at any time depends merely upon the last man with whom he has talked." Refrain from stating an opinion or promoting an undertaking until you have had a reasonable opportunity to obtain and study the facts. Thereafter see it through if at all possible, unless fresh evidence makes it folly to persist. Obviously the extremes of bullheadedness and dogmatism should be avoided, but remember that reversed decisions will be held against you.

Don't be timid--speak up--express yourself and promote your ideas. Every young man should read Emerson's essay on "Self Reliance." Too many new men seem to think that their job is simply to do what they're told to do, along the lines laid down by the boss. Of course there are times when it is very wise and prudent to keep your mouth shut, but, as a rule, it pays to express your point of view whenever you can contribute something. The quiet mousey individual who says nothing is usually credited with having nothing to say.

It frequently happens in any sort of undertaking that nobody is sure of just how the matter ought to be handled; it's a question of selecting some kind of program with a reasonable chance of success. This is commonly to be observed in engineering-office conferences. The first man to speak up with a definite and plausible proposal has better than an even chance of carrying the floor, provided only that the scheme is definite and plausible. (The "best" scheme usually cannot be recognized as such in advance.) It also happens that the man who talks most knowingly and confidently about the matter will very often end up with the assignment to carry out the project. If you do not want the job, keep your mouth shut and you'll be overlooked, but you'll also be overlooked when it comes time to assign larger responsibilities.

Before asking for approval of any major action, have a definite plan and program worked out to support it. Executives very generally and very properly will refuse to approve any proposed undertaking that is not well planned and thought through as regards the practical details of its execution. Quite often a young man will propose a project without having worked out the means of accomplishing it, or weighing the actual advantages against the difficulties and costs. This is the difference between a "well-considered" and a "half-baked" scheme.

Strive for conciseness and clarity in oral or written reports. If there is one bane of an executive's existence, it is the man who takes a half-hour of rambling discourse to tell him what could be said in one sentence of twenty words. There is a curious and widespread tendency among engineers to surround the answer to a simple question with so many preliminaries and commentaries that the answer itself can hardly be discerned. It is so difficult to get a direct answer out of some men that their usefulness is thereby greatly diminished. The tendency is to explain the answer before answering the question. To be sure, very few questions admit of simple answers without qualifications, but the important thing is to state the crux of the matter as succinctly as possible first. On the other hand, there are times when it is very important to add the pertinent background or other relevant facts to illuminate a simple statement. The trick is to convey the maximum of significant information in the minimum time, a valuable asset to any man.

An excellent guide in this respect may be found in the standard practice of newspapers in printing the news. The headlines give 90 per cent of the basic facts. If you have the time and the interest to read further, the first paragraph will give you most of the important particulars. Succeeding paragraphs simply give details of progressively diminishing significance. To fit an article into available space, the editor simply lops off paragraphs from the rear end, knowing that relatively little of importance will be lost. You can hardly do better than to adopt this method in your own reports, presenting your facts in the order of importance, as if you might be cut off any minute.

Be extremely careful of the accuracy of your statements. This seems almost trite, and yet many engineers lose the confindence of their superiors and associates by habitually guessing when they do not know the answer to a direct question, It is certainly important to be able to answer questions concerning your responsibilities, but a wrong answer is worse than no answer. If you do not know, say so, but also say, "I'll find out right away." If you are not certain, indicate the exact degree of certainty or approximation upon which your answer is based. A reputation for dependability and reliability can be one of your most valuable assets.

This applies, of course, to written matter, calculations, etc., as well as to oral reports. It is definitely bad business to submit a report to the boss for approval without first carefully checking it yourself, and yet formal reports are sometimes turned in full of glaring errors and omissions.

In Relation To The Boss

Every executive must know what's going on in his bailiwick. This principle is so elementary and fundamental as to be axiomatic. It follows from the very obvious fact that a man cannot possibly manage his business successfully unless he knows what's going on in it. It applies to minor executives and other individuals charged with specific responsibilities as well as to department heads. No one in his right mind will deny the soundness of the principle and yet it is very commonly violated or overlooked. It is cited here because several of the rules which follow are concerned with specific violations of this cardinal requirement.

Do not overlook the fact that you're working for your boss. This sounds simple enough, but some engineers never get it. By all means, you're working for society, the company, the department, your family, and yourself, but primarily you should be working for and through your boss. And your boss is your immediate superior, to whom you report directly. As a rule, you can serve all other ends to best advantage by working for him, assuming that he's approximately the man he ought to be. It is not uncommon for young engineers, in their impatient zeal to get things done, to ignore the boss, or attempt to go over or around him. Sometimes they move a little faster that way, for a while, but sooner or later they find that such tactics cannot be tolerated in a large organization. Generally speaking, you cannot get by the boss; he determines your rating and he rates you on your ability to cooperate, among other things. Besides, most of us get more satisfaction out of our jobs when we're able to give the boss our personal loyalty, with the feeling that we're helping him to get the main job done.

Be as particular as you can in the selection of your boss. In its effect upon your engineering career, this is second in importance only to the selection of proper parents. In most engineering organizations the influence of the senior engineer, or even the section head, is a major factor in molding the professional character of younger engineers. Long before the days of universities and textbooks, master craftsmen in all the arts absorbed their skills by apprenticeship to master craftsmen.

It is very much as in the game of golf; a beginner who constantly plays in company with "dubs" is very apt to remain a "dub" himself, no matter how faithfully he studies the rules, whereas even a few rounds with a "pro" will usually improve a novice's game.

But, of course, it is not always possible to choose your boss advisedly. What if he turns out to be somewhat less than half the man he ought to be? There are only two proper alternatives open to you; (a) accept him as the representative of a higher authority and execute his policies and directives as effectively as possible, or (b) transfer to some other outfit at the first opportunity. A great deal of mischief can be done to the interests of all concerned (including the company) if some other alternative is elected, particularly in the case of younger men. Consider the damage to the efficiency of a military unit when the privates, disliking the leader, ignore or modify orders to suit their individual notions! To be sure, a business organization is not a military machine, but it is not a mob, either.

One of the first things you owe your boss is to keep him informed of all significant developments. This is a corollary of the preceding rules: An executive must know what's going on. The main question is: How much must he know--how many of the details? This is always a difficult matter for the new man to get straight. Many novices hesitate to bother the boss with too many reports, and it is certainly true that it can be overdone in this direction, but in by far the majority of cases the executive's problem is to extract enough information to keep adequately posted. For every time he has to say, "Don't bother me with so many details," there will be three times he will say, "Why doesn't someone tell me these things?" Bear in mind that he is constantly called upon to account for, defend, and explain your activities to the "higher-ups," as well as to coordinate these activities into a larger plan. In a nutshell, the rule is therefore to give him promptly all the information he needs for these two purposes.

Whatever the boss wants done takes top priority. You may think you have more important things to do first, but unless you obtain permission it is usually unwise to put any other project ahead of a specific assignment from your own boss. As a rule, he has good reasons for wanting his job done *now*, and it is apt to have a great deal more bearing upon your rating than less conspicuous projects which may appear more urgent.

Also, make a note of this: If you are instructed to do something and you subsequently decide it isn't worth doing (in view of new data or events) do not just let it die, but inform the boss of your intentions and reasons. Neglect of this point has caused trouble on more than one occasion.

Do not be too anxious to follow the boss's lead. This is the other side of the matter covered by the preceding rule. An undue subservience or deference to the department head's wishes is fairly common among young engineers. A man with this kind of psychology may:

1. Plague the boss incessantly for minute directions and approvals.
2. Surrender all initiative and depend upon the boss to do all of his basic thinking for him.
3. Persist in carrying through a design or a program even after new evidence has proved the original plan to be wrong.

This is where an engineering organization differs from any army. In general, the program laid down by the department or section head is tentative, rather than sacred, and is intended to serve only until a better program is proposed and approved.

The rule therefore is to tell your boss what you have done, at reasonable intervals, and ask his approval of any well-considered and properly planned deviations or new projects that you may have conceived.

Regarding Relations with Associates and Outsiders

Never invade the domain of any other division without the knowledge and consent of the executive in charge. This is a very common offense, which causes no end of trouble. Exceptions will occur in respect to minor details, but the rule applies particularly to:

1. The employment of a subordinate. Never offer a man a job, or broach the matter at all, without first securing the permission of his boss. There may be excellent reasons why the man should not be disturbed.
2. Engaging the time or committing the services of a subordinate for some particular project or trip. How would you feel, after promising in a formal meeting to assign one of your men to an urgent project, to discover that some other executive had had the gall to send him on an out-of-town trip without attempting to notify you? Yet it has been done!
3. Dealings with customers or outsiders, with particular reference to making promises or commitments involving another division. In this connection bear in mind especially that, when you are in the "field" or the "districts," you are in the premises of the district manager or local office, and that all transactions must be with the manager's permission just as if you were in his home.
4. Performing any function assigned to another division or individual. Violations of this law often cause bitter resentments and untold mischief. The law itself is based upon three underlying principles:

(a) Most people strongly dislike having anyone "muscle" into their territory, undermining their job by appropriating their functions.
(b) Such interference breeds confusion and mistakes. The man in charge of the job usually knows much more about it than you do, and, even when you think you know enough about it, the chances are better than even that you'll overlook some important factor.
(c) Nine times out of ten when you're performing the other fellow's function you're neglecting your own. It is rarely that any engineer or executive is so caught up on his own

responsibilities that he can afford to take on those of his colleagues.

There is a significant commentary on this last principle which should also be observed: In general you will get no credit or thanks for doing the other fellow's job for him at the expense of your own. But it frequently happens that, if you can put your own house in order first, an understanding of and an active interest in the affairs of other divisions will lead to promotion to a position of greater responsibility. Many a man has been moved up primarily because of a demonstrated capacity for taking care of other people's business as well as his own.

In all transactions be careful to "deal-in" everyone who has a right to be in. It is extremely easy, in a large corporation, to overlook the interests of some division or individual who does not happen to be represented, or in mind, when a significant step is taken. Very often the result is that the step has to be retracted or else considerable damage is done. Even when it does no apparent harm, most people do not like to be left out when they have a stake in the matter, and the effect upon morale may be serious.

Of course there will be times when you cannot wait to stand on ceremony and you'll have to go ahead and "damn the torpedoes." But you cannot do it with impunity too often.

Note particularly that in this and the preceding item the chief offense lies in the invasion of the other man's territory without his knowledge and consent. You may find it expedient on occasions to do the other man's job for him, in order to get your own work done, but you should first give him a fair chance to deliver the goods or else agree to have you take over. If you must offend in this respect, at least you should realize that you are being offensive.

Be careful about whom you mark for copies of letters, memos, etc., when the interests of other departments are involved. A lot of mischief has been caused by young men broadcasting memoranda containing damaging or embarrassing statements. Of course it is sometimes difficult for a novice to recognize the "dynamite" in such a document but, in general, it is apt to cause trouble if it steps too heavily upon someone's toes or reveals a serious shortcoming on anybody's part. If it has wide distribution or if it concerns manufacturing or customer difficulties, you'd better get the boss to approve it before it goes out unless you're very sure of your ground.

Promises, schedules, and estimates are necessary and important instruments in a well-ordered business. Many engineers fail to realize this, or habitually try to dodge the irksome responsibility for making commitments. You *must* make promises based upon your own estimates for the part of the job for which you are responsible, together with estimates obtained from contributing departments for their parts. No one should be allowed to avoid the issue by the old formula, "I can't give a promise because it depends upon so many uncertain factors." Consider the "uncertain factors" confronting a department head who must make up a budget for an entire engineering department for a year in advance! Even the most uncertain case can be narrowed down by first asking, "Will it be done in a matter of a few hours or a few months--a few days or a few weeks?" It usually turns out that it cannot be done in less than three weeks and surely will not require more than five, in which case you'd better say four weeks. This allows one week for contingencies and sets you a reasonable bogie under the comfortable figure of five weeks. Both extremes are bad; a good engineer will set schedules which he can meet by energetic effort at a pace commensurate with the significance of the job.

As a corollary of the foregoing, you have a right to insist upon having estimates from responsible representatives of other departments. But in accepting promises, or statements of facts, it is frequently important to make sure that you are dealing with a properly qualified representative of the other section. Also bear in mind that when you ignore or discount another man's promises you impugn his responsibility and incur the extra liability yourself. Of course this is sometimes necessary, but be sure that you do it advisedly. Ideally, another man's promises should be negotiable instruments, like his personal check, in compiling estimates.

When you are dissatisfied with the services of another section, make your complaint to the individual most directly responsible for the function involved. Complaints made to a man's superiors, over his head, engender strong resentments and should be resorted to only when direct appeal fails. In many cases such complaints are made without giving the man a fair chance to correct the grievance, or even before he is aware of any dissatisfaction.

This applies particularly to individuals with whom you are accustomed to deal directly or at close range, or in cases where you know the man to whom the function has been assigned. It is more formal and in some instances possibly more correct to file a complaint with the head of section or department, and it will no doubt tend to secure prompt results. But there are more than a few individuals who would never forgive you for complaining to their boss without giving them a fair chance to take care of the matter.

Next to a direct complaint to the top, it is sometimes almost as serious an offense to mark a man's boss for a copy of a letter containing a complaint or an implied criticism. Of course the occasion may justify such criticism; just be sure you know what you're doing.

In dealing with customers and outsiders remember that you represent the company, ostensibly with full responsibility and authority. You may be only a few months out of college but most outsiders will regard you as a legal, financial, and technical agent of your company in all transactions, so be careful of your commitments.

PART 2--RELATING CHIEFLY TO ENGINEERING EXECUTIVES

The following is a partial list of basic commandments, readily subscribed to by all executives but practiced only by the really good ones:

Individual Behavior and Technique

Every Executive must know what's going on in his bailiwick. This is repeated here for emphasis, and because it belongs at the head of the list for this section. Just remember that it works both ways, as regards what you owe your associates and subordinates as well as yourself.

Obviously this applies primarily to major or significant developments and does not mean that you should attempt to keep up with all the minor details of functions assigned to subordinates. It becomes a vice when carried to the extent of impeding operations. Nevertheless, the basic fact remains that the more information an executive has, the more effectively he can manage his business.

Do not try to do it all yourself. This is another one of those elementary propositions that everyone will endorse and yet violations are quite common. It's bad business; bad for you, bad for the job, and bad for your men. You must delegate responsibility even if you could cover all of the ground yourself. It isn't wise to have so much depend upon one man and it's very unfair to your men. It is often said that every executive should have his business so organized that he could take a month's vacation at any time and have everything go along smoothly. The most common excuse for hogging the whole job is that subordinates are too young or inexperienced. It's part of your job to develop your men, which includes developing initiative, resourcefulness, and judgment. The best way to do this is to load them up with all the responsibility they can carry without danger of serious embarrassment to the department. Any self-respecting engineer resents being babied, to the extent where he cannot act on the most trivial detail without express approval of the department head.

On the other hand, it must be granted that details are not always trivial and it may sometimes require a meeting of the management committee to change the length of a screw in a critical piece of mechanism in high production. It's simply a matter of making sure that all items are handled by men of appropriate competence and experience.[1]

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[1] "Administrative Organization for a Small Manufacturing Firm," by Willis Rabbe, MECHANICAL ENGINEERING, Vol. 63, 1941, pp. 517-520.

Put first things first, in applying yourself to your job. Since there usually isn't time for everything, it is essential to form the habit of concentrating on the important things first. The important things are the things for which you are held directly responsible and accountable, and if you aren't sure what these are you'd better find out mighty quick and fix them clearly in mind. Assign these responsibilities top priority in budgeting your time; then delegate as many as possible of the items which will not fit into your schedule. It is a good general rule never to undertake any minor project or chore that you can get someone else or some other department to do for you, so long as it is not an essential part of your job. For example, if your job is building motors it's a mistake to spend time designing special vibration or sound meters for testing them if you can get the laboratory to do it for you.

In handling special problems of this sort, it is usually good diplomacy to let some local office do the job, if they can, before importing experts from another plant or company.

The practice of drawing upon all available resources for assistance can frequently be applied to advantage in respect to your major products, as well as in minor details. This is especially true in a large organization where the services of experts, consulting engineers, laboratories, and other departments are available either at no cost or for much less than it would cost you to get the answer independently. In fact, there may well be cases in which it would be wise for you to limit yourself, personally or as a business manager, to performing only those functions to which you can bring some special talent, skill, or contribution, or in which you enjoy some natural advantage. Some companies, for example, have achieved outstanding success by virtue of their special genius for merchandising the products of others, or by concentrating on the manufacture of a standard competitive article so as to capture the market by lowering the price. Likewise the aircraft companies generally exploit their special aeronautical skill, leaving development of engines, superchargers, propellers, and other components to specialists in these fields. Few of us are versatile enough to excel in more than one or two talents.

Cultivate the habit of "boiling matters down" to their simplest terms. The faculty for reducing apparently complicated situations to their basic, essential elements is a form of wisdom that must usually be derived from experience, but there are marked differences between otherwise comparable individuals in this respect. Some people seem eternally disposed to "muddy the water;" or they "can never see the woods for the trees," etc. Perhaps a man cannot correct such an innate tendency simply by taking thought, but it appears to be largely a matter of habit, a habit of withdrawing mentally to a suitable vantage point so as to survey a mass of facts in their proper perspective, or a habit of becoming immersed and lost in a sea of detail. Make it a practice to integrate, condense, summarize, and simplify your facts rather than to expand, ramify, complicate, and disintegrate them.

Many meetings, for example, get nowhere after protracted wrangling until somebody finally says, "Well, gentlemen, it all boils down simply to this,...", or "Can't we agree, however, that the basic point at issue is just this,...", or, "After all, the essential fact remains that..."

This sort of mental discipline, which instinctively impels a man to go down to the core to get at the crux of the matter, is one of the most valuable qualities of a good executive.[2]

Do not get excited in engineering emergencies--keep your feet on the ground. This is certainly trite enough, and yet an engineering group will sometimes be thrown into a state of agitation bordering on panic by some minor crisis. This refers especially to bad news from the factory or the field regarding some serious and embarrassing difficulty, such as an epidemic of equipment failures. Most crises aren't half as bad as they appear at first, so make it a point to minimize rather than magnify a bad situation. Do not ignore signs of trouble and get caught napping, but learn to distinguish between isolated cases and real epidemics. The important thing is to get the facts first, as promptly and as directly as possible. Then act as soon as you have enough evidence from responsible sources to enable you to reach a sound decision.

Engineering meetings should not be too large or too small. Many executives carry their aversion for large meetings to the point of a phobia. This is reflected in the common saying that nothing worth while is ever accomplished in a large meeting. It is true enough that large meetings frequently dissipate the subject over a number of conflicting or irrelevant points of view, in a generally superficial manner. But this is almost entirely a matter of the competence of the chairman. A considerable amount of skill is required to manage a sizable meeting so as to keep it on the proper subject, avoiding long-winded disgressions or reiterations of the arguments. It should be the function of the chairman, or the presiding senior executive, to bring out the pertinent facts bearing upon the matter, in their logical order, and then to secure agreement upon the various issues by (a) asking for general assent to concrete proposals, or (b) taking a vote, or (c) making arbitrary decisions. Engineering meetings may degenerate into protracted wrangles for lack of competent direction. The danger in this respect seems to be about in proportion to the size of the meeting.

Small meetings, three or four persons, can usually hammer out a program or dispose of knotty problems much more effectively. The chief drawback lies in the possibility that all interested parties may not be represented, and considerable loss or mischief may result from failure to take account of significant facts or points of view. Apart from the actual loss involved, strong resentment or discouragement may be engendered in the neglected parties. (The Revolutionary War was brought about largely as a result of the fact that the Colonies were not represented in the British Parliament.)

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[2] See also: "Psychology for Executives," by Elliott Dunlap Smith, Harper & Bros., New York, N. Y., 1935.

There will doubtless be cases in which it is neither feasible nor desirable to have all interested parties represented in an engineering discussion, particularly if the participants are well informed. But in general it is fitting, proper, and helpful to have the man present whose particular territory is under discussion.

An excellent expedient for avoiding the objections to either extreme in this respect is to keep the meeting small, calling in each keyman when his particular responsibility is being discussed.

In any kind of a meeting the important thing is to face the issues and dispose of them. All too often there is a tendency to dodge the issues, postponing action until a later date, or "letting the matter work itself out naturally." Matters will always work out "naturally" if the executive function of control is neglected but this represents a low order of "management," Count any meeting a failure which does not end up with a definite understanding as to what's going to be done; who's going to do it, and when. This should be confirmed in writing (minutes).

Cultivate the habit of making brisk, clean-cut decisions. This is, of course, the most difficult and important part of an executive's job. Some executives have a terrific struggle deciding even minor issues, mainly because they never get over being afraid of making mistakes. Normally, facility comes with practice, but it can be hastened by observing a few simple principles.

1. Decisions will be easier and more frequently correct if you have the essential facts at hand. It will therefore pay you to keep well informed, or else to bring out the relevant facts before attempting a decision. However, it is sometimes said that anybody can make decisions when all of the facts are at hand, whereas an executive will make the same decisions without waiting for the facts.[3] To maintain a proper balance in this respect, when in doubt ask yourself the question: "Am I likely to lose more by giving a snap judgment or by waiting for more information?"

2. The application of judgment can be facilitated by formulating it into principles, policies, and precepts in advance. The present paper is an attempt to formulate experience for this purpose. Make up your own code, if you will, but at least have some sort of code, for much the same reason that you memorize the axioms of Euclid or Newton's laws of motion.

3. You do not have to be right every time. It is said that a good executive needs to be right only 51 per cent of the time (although a little better margin would obviously be healthy).

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[3] See "Definition of an Executive," by H. S. Osborne, ELECTRICAL ENGINEERING, vol. 61, August, 1942, p. 429.

4. The very fact that a decision is difficult usually means that the advantages and drawbacks of the various alternatives are pretty well balanced, so that the net loss cannot amount to much in any event. In such cases it is frequently more important to arrive at some decision--any decision--promptly than to arrive at the best decision ultimately. So take a definite position and see it through.

5. It is futile to try to keep everybody happy in deciding issues involving several incompatible points of view. By all means give everyone a fair hearing, but after all parties have had their say and all facts are on the table, dispose of the matter decisively even if someone's toes are stepped on. Otherwise the odds are that all parties will end up dissatisfied, and even the chief beneficiary will think less of you for straddling the issue.

The following criteria are helpful in choosing a course of action when other factors are indecisive; ask yourself these questions:

(a) Does it expedite and progress the undertaking, or does it smack of procrastination and delay?
(b) Is it fair and square and aboveboard?
(c) Is it in line with established custom, precedence, or policy? A good reason is generally required for a departure.
(d) Is it in line with a previous specific decision or understanding? Even a good reason for making a change will sometimes not offset the unfortunate impression of apparent instability. "He can't make up his own mind" is a common reaction. (Observe, however, that this criterion is suggested only "when other factors are indecisive." By all means have the courage of your convictions when the change is justifiable.)
(e) what are the odds? Can I afford to take the chance? How does the possible penalty compare with the possible gain, in each of the alternatives offered? Very often you can find a solution wherein the worst possible eventuality isn't too bad, in relation to the possible gains.

Do not allow the danger of making a mistake to inhibit your initiative to the point of "nothing ventured, nothing gained." It is much healthier to expect to make mistakes, take a few good risks now and then, and take your medicine when you lose. Moreover, there are few mistakes that cannot be turned into profit somehow, even if it's only in terms of experience.

Finally, it should be observed that having "the courage of your convictions" includes having the courage to do what you know to be right, technically as well as morally, without undue regard for possible criticism or the necessity for explaining your actions. Many seemingly embarrassing situations can readily be cleared up, or even turned to advantage, merely by stating the simple, underlying facts of the matter. It boils down to a very straightforward proposition: If your reasons for your actions are sound, you should not worry about having to defend them to anyone; if they're not sound you'd better correct them promptly, instead of building up an elaborate camouflage.

Do not overlook the value of suitable "preparation" before announcing a major decision or policy. When time permits, it is frequently good diplomacy to prepare the ground for such announcements by discussing the matter in advance with various keymen or directly interested parties. This is, in fact, an elementary technique in diplomatic and political procedure, but it is all too often ignored in engineering practice. Much embarrassment and bad feeling can be caused by announcing a major change or embarking upon a new program or policy without consulting those directly affected or who are apt to bring up violent objections, with good reason later on.[4]

Handling Design and Development Projects

Beware of the "perils of security" in planning your engineering programs. It is one of the fundamental anomalies of human experience that too much preoccupation with the pursuit of security is very apt to lead to greater danger and insecurity. In a competitive world you *must* take chances--bold and courageous chances--or else the other fellow will, and he will win out just often enough to keep you running, all out of breath, trying to catch up. So it behooves you as an engineering executive to "stick your neck out," and keep it out, by undertaking stiff development programs, setting a high mark to shoot at, and then working aggressively to realize your objectives. With competent direction any representative engineering organization will work its way out of a tight spot, every time, under the pressure of the emergency. If you do not like such "emergencies," just remember that, if you do not create your own emergencies in advance, your competition will create them for you at a much more embarrassing time later on.

In order to minimize the risk it is good policy to hedge against the failure of a new project by providing an alternative, or an "out" to fall back on, wherever practicable. You can go after bigger stakes with impunity when you have suitably limited your possible losses in such a manner.

Plan your work, then work your plan. The following formula for carrying out a development or design project seems to be standard in the best engineering circles:

(a) Define your objectives.
(b) Plan the job, by outlining the steps to be accomplished.
(c) Prepare a definite schedule.
(d) Assign definite responsibilities for each item.
(e) Make sure that each man has sufficient help and facilities.
(f) Follow up; check up on progress of the work.
(g) Revise your schedule as required.
(h) Watch for "bottlenecks," "log-jams," and "missing links;" hit lagging items hard.
(i) Drive to a finish on time.

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[4] See also: "The Technique of Executive Control," by Erwin Haskell Schell. Fifth edition, Book Co., Inc., New York, N.Y., 1942.

Plan your development work far enough ahead of production so as to meet schedules without a wild last-minute rush. In the nature of things it seems inevitable that the group responsible for design engineering is also in the best position to take care of development projects. This is due to the intimate contacts of the designers with the practical problems of production, performance, and market requirements. But it is also true that very considerable foresight is required to offset the natural tendency of designers to become preoccupied with immediate problems of this nature, at the expense of the long-range development program, which is not so urgent and pressing. It is therefore the function of management to exercise sufficient "vision" to anticipate trends and initiate research and development projects before the demand becomes uncomfortably urgent. This means starting such projects soon enough, i.e., six months, a year, or even two years in advance, to allow sufficient time to carry out all of the necessary steps in a well-ordered program.

Even when the development of new designs simply means a rehash of old fundamentals in new dress, it is important to plan the program early enough and to provide for all stages in the process of getting the product on the market. For example, the following steps may be required to carry through the development of a typical peace time product:

(a) Market survey.
(b) Preparation of commercial specifications (features and ratings agreed upon jointly by commercial and design divisions)
(c) Preliminary design.
(d) Build and test preliminary sample.
(e) Final design.
(f) Build and test final samples.
(g) Preliminary planning and costs.
(h) Engineering release of final drawings for production.
(i) Final planning and costs.
(j) Ordering materials and tools.
(k) Preparation of manufacturing and test instructions; application, installation, operating and service manuals; replacement-parts catalogue, publicity releases.
(l) Initial production.
(m) Test production samples.
(n) Minor design changes to correct errors and expedite production.

Obviously, some of these activities can be carried on concurrently, but unless they are all suitably provided for there is very apt to be some awkward stumbling and bungling along the way.

Be careful to "freeze" a new design when the development has progressed far enough. Of course it is not always easy to say how far is "far enough" but, in general, you have gone far enough when you can meet the design specifications and costs, with just enough time left to complete the remainder of the program on schedule. The besetting temptation of the designing engineer is to allow himself to be led on by one glittering improvement after another, pursuing an elusive perfection that leads him far past the hope of ever keeping his promises and commitments. Bear in mind that there will always be new design improvements coming along, but it is usually better to get started with what you have on time, provided only that it is up to specifications as regards features, quality, and cost.

Constantly review developments and other activities to make certain that actual benefits are commensurate with costs in money, time, and manpower. Not infrequently developments are carried along by virtue of Newton's first law of motion long after they have ceased to yield a satisfactory return on the investment. The occasion for vigilance in this respect is obvious enough; it is cited here simply as a reminder.

Make it a rule to require, and submit, regular periodic progress reports, as well as final reports on completed projects. However irksome such chores may seem, your business simply isn't fully organized and controlled until you have established this practice, as regards reports to your superiors as well as from your subordinates. There appears to be no other regimen quite so compelling and effective in requiring a man to keep his facts properly assembled and appraised.

It is further true that, generally speaking, an engineering project is not really finished until it is properly summarized, recorded, and filed in such a manner that the information can readily be located and utilized by all interested parties. An enormous amount of effort can be wasted or duplicated in any engineering department when this sort of information is simply entrusted to the memory of individual engineers.

Notes Respecting Organization[5]

Do not have too many men reporting directly to one man. As a rule, not more than six or seven men should report to one executive in an engineering organization. Occasionally a strong energetic leader will deal directly with fifteen or twenty engineers, in which case he is usurping the positions and functions of several group leaders, burdening himself with too much detail, and depriving the men of adequate supervision.

Assign definite responsibilities. It is extremely detrimental to morale and efficiency when no one knows just what his job is or what he is responsible for. If assignments are not made clear there is apt to be interminable bickering, confusion, and bad feeling. Do not keep tentative organization changes hanging over people. It is better to dispose of a situation promptly, and change it later, than to hold up a decision simply because you might want to change it. It is again a matter of facing issues squarely; it is easier to "just wait and see how things work out" but, beyond the minimum time required to size up personnel, it's not good management.

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[5] For a more authoritative discussion of this subject, see the excellent series of papers on "Organization and Management of Engineering," **ELECTRICAL ENGINEERING**, vol. 61, Aug., 1942, pp. 422-429.

Insofar as possible, avoid divided responsibility for specific functions. Ideally each man should have full authority and control over all of the factors essential to the performance of his particular function. This is commonly expressed in the aphorism that authority must be commensurate with responsibility. In practice this is seldom possible of fulfillment; we must all depend upon the contributions of others at some point in the process. Still the amount of dependency should be kept to the practical minimum, for it is extremely difficult for a man to get anything done if he must eternally solicit the voluntary co-operation or approval of too many other parties. This is what is known as being "organized to prevent things from getting done."

The logical answer to the problem of divided responsibility (or "division of labor") is co-ordination. If any activity, such as the design of a product, must be divided into development, design, drafting, and production engineering, these functions should obviously be co-ordinated by a single responsible engineer.

If you haven't enough legal authority assume as much as you need. During the Civil War a Confederate officer one evening found that his supply train was held up by a single Union battery which was dropping shells accurately into a narrow mountain pass. Without even changing his uniform, he rode around to the rear of the battery, and, coming upon them suddenly, sharply ordered them to swing their guns around to another point. He was obeyed with alacrity because he acted as if he expected to be obeyed. He rode off to rejoin his command, and led them through the pass before anyone discovered that he had exceeded his authority.

Of course such tactics are not recommended for general use, but the story illustrates the fact that quite a lot can be accomplished, on occasions, without full administrative sanction. The important thing is to exercise sufficient care to avoid running afoul of the interests and authority of others.

This injunction is based upon three elementary facts of experience:

1. A man will frequently be held responsible for a good deal more than he can control by directly delegated authority.
2. A very considerable amount of authority can be assumed with complete impunity if it is assumed discreetly, and with effective results. People in general tend to obey a man who appears to be in charge of any situation, provided that he appears to know what he is doing and obtains the desired results.
3. Most executives will be very pleased to confirm such authority in their subordinates when they see it being exercised effectively. Executives in general have much more trouble pushing their men ahead than in holding them back.

Do not create "bottlenecks." Co-ordination of minor routine affairs is sometimes carried too far, when a single individual must pass upon each transaction before it can be carried out. Such rigid control can easily cause more trouble than the original liability. Fortunately, bottlenecks are usually recognized early in the game, and it is easy to avoid them by designating alternates, or by allowing freedom of action in emergencies, with the proviso that the proper party be notified at the first opportunity.

Assign responsibilities for technical subjects, as well as for specific products, in setting up your engineering organization. This is a practice which could be used to advantage in design sections more frequently than it is. The idea is to assign dual responsibilities to each engineer; (a) for a particular product or line of apparatus, and (b) for a technical specialty, such as lubrication, heat transfer, surface finishes, magnetic materials, welding, fluid flow, etc. These assignments should be made known to all members of the group, with the request that all pertinent material on each subject be referred to the proper specialist, who will act as consultant and as contact man with laboratories, etc., for the entire section. It may, of course, be desirable to assign full time specialists to important subjects when the business can afford it; the main point is to establish pools of specialized knowledge rather than to expect each designer to know all that he needs to know about the principal arts and sciences which are common to the various products of the department.

What Every Executive Owes His Men

Promote the personal and professional interests of your men on all occasions. This is not only an obligation, it is the opportunity and the privilege of every executive.

As a general principle, the interests of individual engineers coincide with the company's interest, i.e., there is, or should be, no basic conflict. The question of which should be placed first is, therefore, rarely encountered in practice, although it is clear that, in general, the company's interests, like those of the state or society, must take precedence. It is one of the functions of management to reconcile and merge the two sets of interests to their mutual advantage, since they are so obviously interdependent.

It should be obvious that it is to the company's advantage to preserve the morale and loyalty of individual engineers, just as it is common policy to maintain proper relations with the labor unions. The fact is that attempts to organize engineers into unions have failed simply because the engineers have been confident that their interests have been looked after very conscientiously and very adequately by responsible executives.

Morale is a tremendously important factor in any organization. It is founded primarily upon confidence, and it reaches a healthy development when the men feel that they will always get a square deal plus a little extra consideration on occasions.

Specific injunctions under this principle are cited in succeeding items.

Do not hang onto a man too selfishly when he is offered a better opportunity elsewhere. It's a raw deal to stand in the way of a man's promotion just because it will inconvenience you to lose him. You are justified in shielding him from outside offers only when you are sincerely convinced that he has an equal or better opportunity where he is. Moreover, you should not let yourself get caught in a position where the loss of any man would embarrass you unduly. Select and train runners-up for all keymen, including yourself.

Do not short-circuit or override your men if you can possibly avoid it. It is very natural, on occasions, for an executive to want to exercise his authority directly in order to dispose of a matter promptly without regard for the man assigned to the job. To be sure, it's your prerogative, but it can be very demoralizing to the subordinate involved and should be resorted to only in real emergencies. Once you give a man a job, let him do it, even at the cost of some inconvenience to yourself. Never miss a chance to build up the prestige of your men. And more than a little mischief can be done by exercising authority without sufficient knowledge of the details of the matter.

You owe it to your men to keep them properly informed. Next to responsibility without authority comes responsibility without information, in the catalogue of raw deals. It is very unfair to expect a man to acquit himself creditably when he is held responsible for a project without adequate knowledge of its past history, present status, or future plans. An excellent practice, followed by many top-flight executives, is to hold occasional meetings of section heads to acquaint them with major policies and developments in the business of the department and the company, so that all will know what's going on.

An important part of the job of developing a man is to furnish him with an ample background of information in his particular field, and as a rule this involves a certain amount of travel. There are occasions when it is worth while to send a young man along on a trip for what he can get out of it, rather than what he can contribute to the job.

Do not criticize one of your men in front of others, especially his own subordinates. This obviously damages prestige and morale.

Also, be very careful not to criticize a man when it's really your own fault. Not infrequently, the real offense can be traced back to you, as when you fail to advise, or warn, or train the man properly. Be fair about it.

Show an interest in what your men are doing. It is definitely discouraging to a man when his boss manifests no interest in his work, as by failing to inquire, comment, or otherwise take notice of it.

Never miss a chance to commend or reward a man for a job well done. Remember that your job is not just to criticize and browbeat your men into getting their work done. A first-rate executive is a leader as well as a critic. The better part of your job is, therefore, to help, advise, encourage, and stimulate your men.

On the other hand, this does not mean mollycoddling. By all means get tough when the occasion justifies it. An occasional sharp censure, when it is well deserved, will usually help to keep a man on his toes. But if that's all he gets, he is apt to go a bit sour on the job.

Always accept full responsibility for your group and the individuals in it. Never "pass the buck" or blame one of your men, even when he has "let you down" badly, in dealings with outsiders. You are supposed to have full control and you are credited with the success as well as the failure of your group.

Do all that you can to see that each of your men gets all of the salary that he's entitled to. This is the most appropriate reward or compensation for outstanding work, greater responsibility, or increased value to the company. (Any recommendation for an increase in salary must be justified on one of these three bases.)

Include interested individuals in introductions, luncheons, etc., when entertaining visitors. Obviously, this can be overdone, but if you're entertaining a visiting specialist, it is good business, as well as good manners, to invite the corresponding specialist in your own department to go along.

Do all that you can to protect the personal interests of your men and their families, especially when they're in trouble. Do not confine your interest in your men rigidly within the boundaries of "company business."

Try to get in little extra accommodations when justifiable. For example, if you're sending a man to his home town on a business trip, schedule it for Monday, so that he can spend Sunday with his family, if it makes no difference otherwise.

Considerations of this sort make a "whale" of a difference in the matter of morale and in the satisfaction an executive gets out of his job. The old-fashioned "slave-driver" is currently regarded in about the same light as Heinrich Himmler. Treat your men as human beings making up a team rather than as cogs in a machine.

In this connection, it is sometimes advisable to talk things over with a man when you become definitely dissatisfied with his work, or recognize a deficiency which is militating against him. To be sure, it is not always easy, and may require much tact to avoid discouraging or offending the man, but it may well be that you owe it to him. Bear this in mind; if you ultimately have to fire him, you may have to answer two pointed questions: "Why has it taken you five years to discover my incompetence?" and, "Why haven't you given me a fair chance to correct these shortcomings?" Remember that when you fire a man for incompetence, it means not only that he has failed, but also that you have failed.

Part 3--Purely Personal Considerations for Engineers.

The importance of the personal and sociological aspects of our behavior as engineers is brought out in the following quotation (1):[1]

"In a recent analysis of over 4000 cases, it was found that 62 per cent of the employees discharged were unsatisfactory because of social unadaptability, only 38 per cent for technical incompetence."

And yet about 99 per cent of the emphasis in the training of engineers is placed upon purely technical or formal education. In recent years, however, there has been a rapidly growing appreciation of the importance of "human engineering," not only in respect to relations between management and employees but also as regards the personal effectiveness of the individual worker, technical or otherwise. It should be obvious enough that a highly trained technological expert with a good character and personality is necessarily a better engineer and a great deal more valuable to his company than a sociological freak or misfit with the same technical training. This is largely a consequence of the elementary fact that in a normal organization no individual can get very far in accomplishing any worth-while objectives without the voluntary co-operation of his associates; and the quantity and quality of such co-operation is determined by the "personality factor" more than anything else.

This subject of personality and character is, of course, very broad and much has been written and preached about it from the social, ethical, and religious points of view. The following "laws" are drawn up from the purely practical point of view based upon well-established principles of "good engineering practice," or upon consistently repeated experience. As in the preceding sections, the selections are limited to rules which are frequently violated, with unfortunate results, however obvious or bromidic they may appear.

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[1] Numbers in parentheses refer to the Bibliography at the end of the paper.

"Laws" of Character and Personality

One of the most important personal traits is the ability to get along with all kinds of people. This is rather a comprehensive quality but it defines the prime requisite of personality in any type of industrial organization. No doubt this ability can be achieved by various formulas, although it is probably based mostly upon general, good-natured friendliness, together with fairly consistent observance of the "Golden Rule." The following "do's and don'ts" are more specific elements of such a formula:

1. Cultivate the tendency to appreciate the good qualities, rather than the shortcomings of each individual.

2. Do not give vent to impatience and annoyance on slight provocation. Some offensive individuals seem to develop a striking capacity for becoming annoyed, which they indulge with little or no restraint.

3. Do not harbor grudges after disagreements involving honest differences of opinion. Keep your arguments on an objective basis and leave personalities out as much as possible.

4. Form the habit of considering the feelings and interests of others.

5. Do not become unduly preoccupied with your own selfish interests. It may be natural enough to "look out for Number One first," but when you do your associates will leave the matter entirely in your hands, whereas they will be much readier to defend your interests for you if you characteristically neglect them for unselfish reasons.

This applies particularly to the matter of credit for accomplishments. It is much wiser to give your principal attention to the matter of getting the job done, or to building up your men, than to spend too much time pushing your personal interests ahead of everything else. You need have no fear of being overlooked; about the only way to lose credit for a creditable job is to grab for it too avidly.

6. Make it a rule to help the other fellow whenever an opportunity arises. Even if you're mean-spirited enough to derive no personal satisfaction from accommodating others, it's a good investment. The business world demands and expects cooperation and teamwork among the members of an organization. It's smarter and pleasanter to give it freely and ungrudgingly, up to the point of unduly neglecting your own responsibilities.

7. Be particularly careful to be fair on all occasions. This means a good deal more than just being fair, upon demand. All of us are frequently unfair, unintentionally, simply because we do not habitually view the matter from the other fellow's point of view, to be sure that his interests are fairly protected. For example, when a man fails to carry out an assignment, he is sometimes unjustly criticized when the real fault lies with the

executive who failed to give him the tools to do the job. Whenever you enjoy some natural advantage, or whenever you are in a position to injure someone seriously, it is especially incumbent upon you to "lean over backwards" to be fair and square.

8. Do not take yourself or your work too seriously. A normal healthy sense of humor, under reasonable control, is much more becoming, even to an executive, than a chronically soured dead-pan, a perpetually unrelieved air of deadly seriousness, or the pompous solemn dignity of a stuffed owl. The Chief Executive of the United States smiles easily or laughs heartily, on appropriate occasions, and even his worst enemies do not attempt to criticize him for it. It is much better for your blood pressure, and for the morale of the office, to laugh off an awkward situation now and then than to maintain a tense tragic atmosphere of stark disaster whenever matters take an embarrassing turn. To be sure, a serious matter should be taken seriously, and a man should maintain a quiet dignity as a rule, but it does more harm than good to preserve an oppressively heavy and funereal atmosphere around you.

9. Put yourself out just a little to be genuinely cordial in greeting people. True cordiality is, of course, spontaneous and should never be affected, but neither should it be inhibited. We all know people who invariably pass us in the hall or encounter us elsewhere without a shadow of recognition. Whether this be due to inhibition or preoccupation we cannot help feeling that such unsociable chumps would not be missed much if we never saw them again. On the other hand, it is difficult to think of anyone who is too cordial, although it can doubtless be overdone like anything else. It appears that most people tend naturally to be sufficiently reserved or else over-reserved in this respect.

10. Give the other fellow the benefit of the doubt if you are inclined to suspect his motives, especially when you can afford to do so. Mutual distrust and suspicion breed a great deal of absolutely unnecessary friction and trouble, frequently of a very serious nature. This is a very common phenomenon, which can be observed among all classes and types of people, in international as well as local affairs. It is derived chiefly from misunderstandings, pure ignorance, or from an ungenerous tendency to assume that a man is guilty until he is proved innocent. No doubt the latter assumption is the "safer" bet, but it is also true that if you treat the other fellow as a depraved scoundrel, he will usually treat you likewise, and he will probably try to live down to what is expected of him. On the other hand you will get much better co-operation from your associates and others if you assume that they are just as intelligent, reasonable, and decent as you are, even when you know they're not (although the odds are 50:50 that they are). It isn't a question of being naive or a perpetual sucker; you'll gain more than you lose by this practice, with anything more than half-witted attention to the actual odds in each case.

Do not be too affable. It's a mistake, of course, to try too hard to get along with everybody merely by being agreeable and friendly on all occasions Somebody will take advantage of you sooner or later, and you cannot avoid trouble simply by running away from it ("appeasement"). You must earn the respect of your associates by demonstrating your readiness to give any man a hell of a good fight if he asks for it. Shakespeare put it succinctly in Polonius' advice to his son (in "Hamlet"): "Beware of entrance to a quarrel; but being in, bear it that the opposed may beware of thee."

On the other hand, do not give ground too quickly just to avoid a fight, when you know you're in the right. If you can be pushed around easily the chances are that you will be pushed around. There will be times when you would do well to start a fight yourself, when your objectives are worth fighting for.

As a matter of fact, as long as you're in a competitive business you're in a fight all the time. Sometimes it's a fight between departments of the same company. As long as it's a good clean fight, with no hitting below the belt, it's perfectly healthy. But keep it on the plane of "friendly competition" as long as you can. (In the case of arguments with your colleagues, it is usually better policy to settle your differences out of court, rather than to take them to the boss for arbitration.)

Likewise, in your relations with subordinates it is unwise to carry friendliness to the extent of impairing discipline. There are times when the best thing that you can do for a man (and the company) is to fire him, or transfer him. Every one of your men should know that whenever he deserves a good "bawling out" he'll get it, every time. The most rigid discipline is not resented so long as it is reasonable, impartial, and fair, especially when it is balanced by appropriate rewards, appreciation, and other compensations as mentioned in Part 2. Too much laxity or squeamishness in handling men is about as futile as cutting off a dog's tail an inch at a time to keep it from hurting so much. If you do not face your issues squarely, someone else will be put in your place who will.

Regard your personal integrity as one of your most important assets. In the long pull there is hardly anything more important to you than your own self-respect and this alone should provide ample incentive to maintain the highest standard of ethics of which you are capable. But, apart from all considerations of ethics and morals, there are perfectly sound and hard-headed business reasons for conscientiously guarding the integrity of your character.

One of the most striking phenomena of an engineering office is the transparency of charcter among the members of any group who have been associated for any lenth of time. In a surprisingly short period each individual is recognized, appraised, and catalogued for exactly what he is, with far greater accuracy than that individual usually realizes. This is true to such a degree that it makes a man appear downright ludicrous when he assumes a pose or otherwise tries to convince us that he is something better than he is. As Emerson puts it: "What you are speaks so loud I cannot hear what you say." In fact it frequently happens that a man is much better known and understood by his associates, collectively, than he knows and understands himself.

Therefore, it behooves you as an engineer to let your personal conduct, overtly and covertly, represent your conception of the very best practical standard of professional ethics, by which you are willing to let the world judge and rate you.

Moreover, it is morally healthy and tends to create a better atmosphere, if you will credit the other fellow with similar ethical standards, even though you may be imposed upon occasionally. The obsessing and overpowering fear of being cheated is the common characteristic of second-and-third-rate personalities. This sort of psychology sometimes leads a man to assume an extremely "cagey" sophisticated attitude, crediting himself with being impressively clever when he is simply taking advantage of his more considerate and fair-minded associates. On the other hand a substantial majority of top-flight executives are scrupulously fair, square, and straightforward in their dealings with all parties. In fact most of them are where they are largely because of this characteristic, which is one of the prime requisites of first-rate leadership.

The priceless and inevitable reward for uncompromising integrity is confidence, the confidence of associates, subordinates, and "outsiders." All transactions are enormously simplified and facilitated when a man's word is as good as his bond and his motives are above suspicion. Confidence is such an invaluable business asset that even a moderate amount of it will easily outweigh any temporary advantage that might be gained by sharp practices.

Integrity of character is closely associated with sincerity, which is another extremely important quality. Obvious and marked sincerity is frequently a source of exceptional strength and influence in certain individuals, particularly in the case of speakers. Abraham Lincoln is a classic example. In any individual, sincerity is always appreciated, and insincerity is quickly detected and discounted.

In order to avoid any misunderstanding, it should be granted here that the average man, and certainly the average engineer, is by no means a low dishonest scoundrel. In fact the average man would violently protest any questioning of his essential honesty and decency, perhaps fairly enough. But there is no premium upon this kind of common garden variety of honesty, which is always ready to compromise in a pinch. The average man will go off the gold standard or compromise with any sort of expediency whenever it becomes moderately uncomfortable to live up to his obligations. This is hardly what is meant by "integrity" and it is certainly difficult to base even a moderate degree of confidence upon the guarantee that you will not be cheated unless the going gets tough.

A little profanity goes a long way. Engineering is essentially a gentlemen's profession, and it ill becomes a man to carry profanity to the point of becoming obnoxiously profane

Unfortunately, profanity is sometimes taken as a mark of rugged he-man virility, but any engineer with such an idea should realize that many a pimply, half-witted, adolescent street urchin will hopelessly outclass him in this respect.

On the other hand, there is no reason why a man should be afraid to say "damn." On appropriate occasions a good hearty burst of colorful profanity may be just a healthy expression of strong feelings. But there is never any occasion for the filthy variety of obscenity, and a really foul mouth will generally inspire nothing but contempt.

Be careful of your personal appearance. Roughly eight out of every ten engineers pay adequate attention to their personal appearance and neatness. The other two offend in respect to one or more of the following items:

1. Suit rumpled or soiled, or else trousers, coat, and vest have nothing in common but their means of support.

2. Shoes, unpolished or dilapidated.

3. Tie, at half-mast or looking like it was tied with one hand. Some individuals seem to own but one tie, which takes an awful beating. Others wear colors contrasting violently with suit or shirt, but this is sometimes a matter of artistic license (if it isn't color blindness).

4. Shirt, frayed at collor or cuffs, or just plain dirty.

5. Hands, dirty.

6. Nails, in deep mourning, chewed off, or else absurdly long. A man doesn't need to be fastidious, but dirty neglected nails immediately and conspicuously identify a careless sloppy individual. (This is especially true in the case of an interview, where first impressions are so important.)

Of course we all know some very good men who are oblivious to such details, so that it cannot be said that all who ignore them are necessarily crude, third-rate, slovenly low-brows, but it is probably a safe bet that all crude, third-rate, slovenly low-brows are offensive in most of these respects.

Do not argue that you cannot afford to look your best; you cannot afford not to. Your associates and superiors notice these details, perhaps more than you realize, and they rate you accordingly.

In this connection, note the following quotation from a recent pamphlet on "employee rating" (2):

"The 'halo effect' simply means that rating of one trait is often influenced by that given to some other trait. Thus an employee who makes a nice appearance and has a pleasant manner is apt to obtain a higher rating on all other traits than he deserves."

Analyze yourself and your men. In the foregoing, it has been assumed that any normal individual will be interested in either:

(a) Advancement to a position of greater responsibility, or

(b) Improvement in personal effectiveness as regards quantity and/or quality of accomplishment.

Either of these should result in increased financial compensation and satisfaction derived from the job.

With reference to item (a), it is all too often taken for granted that increased executive and administrative responsibility is a desirable and appropriate form of reward for outstanding proficiency in any type of work. This may be a mistake from either of two points of view:

1. The individual may be very much surprised to find that he is much less happy in his new job than he thought he was going to be. In many instances young engineers are prone to assume that increased responsibility means mostly increased authority and compensation. Actually, the term "compensation" is well applied, for the extra salary is paid primarily to compensate for the extra burden of responsibility. Of course most people relish the added load, because of the larger opportunities that go with it, but many perfectly normal individuals find it more of a load than anything else. It is not uncommon for an engineer or a scientist to discover, to his dismay, that as soon as he becomes an executive he no longer has time to be an engineer or a scientist. In fact, some executives have time for absolutely nothing else.

2. From the business standpoint, it by no means follows that because a man is a good scientist, he will make a good executive. Many a top-notch technician has been promoted to an administrative position very much to his own and the job's detriment.

These facts should therefore be considered carefully by the man threatened with promotion and by the man about to do the promoting. There are other ways of rewarding a man for outstanding accomplishment.

It is not always easy, however, to decide in advance whether you, or the man in question, would be happier and more effective as an executive or as an individual worker. There is no infallible criterion for this purpose but it will be found, that, in general, the two types are distinguished by the characteristics and qualities listed in Table 1.

TABLE 1. CHARACTERISTIC QUALITIES FOR EXECUTIVE OR INDIVIDUAL WORKERS

Executive	Individual Worker
Extrovert	Introvert
Cordial, affable	Reserved
Gregarious, sociable	Prefers own company
Likes people	Likes technical work
Interested in people	Interested in mechanisms, ideas
Interested in:	Interested in:
Business	Sciences
Costs.	Mathematics
Profit and loss	Literature
Practices	Principles
Ability to get many things done	Ability to get intricate things done
Practical	Idealistic
Extensive (broad perspectives)	Intensive (penetrating)
Synthesist	Analyst
Fast, intuitive	Slow, methodical
Talent for leadership	Independent, self-sufficient
Uses inductive logic	Uses deductive logic
Has competitive spirit	Prefers to "live and let live"
Bold	Modest
Courageous	Retiring
Noisy	Quiet
Aggressive	Restrained
Tough, rugged	Vulnerable, sensitive
Confident	Deferential
Impulsive	Intellectual
Vigorous, energetic	Meditative, philosophical
Opinionated, intolerant	Broad-minded, tolerant
Determined	Adaptable
Impatient	Patient
Enterprising	Conservative

Of course many people represent intermediate types, or mixtures; the attributes given in Table 1 delineate the pronounced types. Nevertheless, if most of your attributes lie in the right hand column the chances are very much against your becoming a successful executive. On the other hand, if you are interested primarily in increasing your effectiveness as an individual worker you would do well to develop some of the strong qualities listed in the left column, to reinforce the virtues on the right.

Two facts stand out sharply in this connection:

1, Whatever your position, and however complacent you may be about it, there is always room for improving your effectiveness; usually plenty of room.

2. Whatever your natural handicaps may be, it is always possible to accomplish such improvement by study and practice, provided only that you have the will, the determination, and the interest to sustain the effort.

It is very much like the design of a piece of apparatus. Any experienced engineer knows that it is always possible to secure substantial improvements by a redesign. When you get into it you will find that there are few subjects more absorbing or more profitable than the design and development of a good engineer! As Alexander Pope wrote many years ago:
"The proper study of mankind is man."

As previously suggested, this applies to the development of your men as well as yourself. It likewise applies to the appraisal and selection of men. After your own character, the next most important factor in your ultimate success is the calibre of your assistants. In fact, there are, doubtless, cases where the character of the executive is not particularly important, provided only that he is smart enough to surround himself with top-notch men to carry the load. In many instances the success or failure of your business will depend upon whether your engineers are slightly above or below the marginal level of competence for the industry.

It is a significant fact that, in the overwhelming majority of cases, the decisive differences in the abilities of engineers are relatively small. In spite of the occasional incidence of a genius or a nit-wit, the great majority of personnel in any industry and the backbone of the large organizations are individuals who vary only slightly from the norm. In general, when executives look over an organization to select a man for a better job, those who are passed up have very few actual shortcomings, but the man who is chosen has the least. Likewise, many top executives are distinguished not so much by marked genius as by relative freedom from defects of character. There is nowhere near enough genius to go around.

This should be particularly heartening to the younger men who view the leaders of industry with awe and wonder upon what meat they feed. Nine out of ten of you have "what it takes" as regards native endowments. The problem is to make the most of what you have.

To this end it will be helpful to study some of the employee rating sheets and charts that have been evolved by various industries. Sample forms and a general discussion of the subject will be found in the pamphlet on "employee rating" (2). It is very noticeable that most of these forms are concerned chiefly with acquired rather than inherited traits. The point is that most of the features upon which individuals are rated represent bad habits or plain ignorance, i.e., features that may be controlled and corrected by conscious effort.

Conclusion

The foregoing "laws" represent only one basic element in the general formula for a successful engineering career. The complete list of essential components is as follows:

(a) The written laws (the arts and sciences).
(b) The unwritten laws, of which the foregoing is admittedly no more than a preliminary and very inadequate summary.

(c) Native endowments (intelligence, imagination, health, energy, etc.).
(d) Luck, chance, opportunities ("the breaks").

The last item is included because good or bad fortune undoubtedly enters into the picture occasionally. Broadly speaking, however, luck tends to average out at a common level over a period of years, and there are more opportunities looking for men than there are men looking for opportunities.

About all that we can do about our native endowments is to conserve, develop, and utilize them to best advantage.

The "unwritten laws," including those that are still unwritten, are needed to give direction to our efforts in this latter respect.

The "written laws" receive plenty of attention during our formal schooling, but our studies are not always extended as effectively as they might be after graduation. In many cases, superior technical knowledge and training represents the marginal consideration in the selection of men for key positions.

To anyone interested in improving his professional effectiveness, further study of both types of laws will yield an excellent return on the investment. Under present conditions, however, most engineering graduates are much closer to the saturation point in respect to the written than to the unwritten variety. A few references are listed in the Bibliography for the benefit of those who may be interested in further excursions into these subjects.

Finally it should be observed that the various principles which have been expounded, like those of the arts and sciences, must be assiduously applied and developed in practice if they are to become really effective assets. It is much easier to recognize the validity of these "laws" than it is to apply them consistently, just as it is easier to accept the doctrines of Christianity than to practice them. The important thing here is to select, insofar as possible, a favorable atmosphere for the development of these professional skills. This is undoubtedly one of the major advantages of employment in a large engineering organization, just as it is advantageous to a young doctor to spend his internship in the Mayo Clinic. Perhaps even more important, as previously mentioned, is the selection of your boss, particularly during those first few years that constitute your engineering apprenticeship. No amount of precept is as effective as the proper kind of example. Unfortunately, there is not nearly enough of this kind of example to go around, and in any event it will behoove you to study the "rules of the game" to develop your own set of principles to guide you in your professional practice.

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CHAPTER THREE

CREATIVE WORK IN ENGINEERING

I. THE CREATION OF NEW DEVICES

We cannot have engineering progress without new designs. Improvements in existing equipment, new devices, and new industries spring from the invention or creation of new types of physical things brought to being through men's imagination.

In the past in mechanical design, and to some extent, in electrical design, a rather high percentage of the inventions have come from men without formal college training who advanced through an informal apprenticeship in the shop, drafting room, or laboratory. To produce many of the new designs of the future, it is almost certain that a greater knowledge of scientific fundamentals will be required than heretofore. New products and new manufacturing industries can come only through the imaginative effort of men with a flair for creative design.

II. DESIGN IN RELATION TO CURRICULUM

The mathematicians use the term "analysis" to refer to such fields of study as functions of a real variable, series, differential and integral calculus, differential equations, etc. These deal with the entity quantity (including time). The term analysis will be used throughout this paper, at least in the general mathematical sense, as a form or type of thinking. It will be contrasted with the word "synthesis" which will be taken to mean the putting together of different things or ideas and will include the notion of a resulting intelligible whole.

The techniques of analysis have been the backbone of much, if not most, engineering teaching, and rightfully so. They pave the way for the statements of "basic principles" which, by definition, enter into a multitude of problems, and lead to their solutions. Also, analysis, as it stems from mathematics, affords us means for attaining sufficient accuracy in a profession where accuracy is of profound importance.

But, analysis is not the answer to all problems in even the technical phases of engineering. For the creation of new designs we usually need the capacity for imagining new combinations of material things and an approximately accurate "sense of the rightness" of these. New designs are not often analyzed into being, but are synthesized by bold qualitative thinking.

We need to consider next the nature of design and development and, at the risk of some inaccuracy, might state that there are two major divisions of each complete problem:

A. There is the initial stage of design which usually deals with questions in a qualitative way. The problem must be discovered and stated, possible methods of solution must be synthesized or invented, and finally an evaluation and classification of the potential methods is required. Even the last often may be done largely at the qualitative level.

B. The more nearly final stage of design deals with matters in a quantitative way. The process selected for the solution of the problem is refined and developed in detail through the application of known techniques of analysis. The basic idea is given form and dimensions through the use of calculations, drawings, scale models, and the construction of pilot models.

In the past, formal engineering education has rarely included practice in the first, but often has included training in the second or more nearly final stage of design work. Instruction in the latter has been characterized by two general procedures. One has been to teach basic design techniques without completely designing any specific device. A great proponent of this procedure was the late B. G. Lamme. In his electrical design schools were taught such subjects as the calculations of magnetic electrostatic and other steady state fields, emfs, mmfs, iron and other losses, cooling and ventilation in electrical apparatus. On occasions both static and rotating equipment might be used to illustrate a single subject, but in general, no machine was completely designed in this school. Another procedure has been to teach some basic design techniques, but primarily to emphasize their use through the derivation and application of formulas which were developed for the design of specific machines.

Each of these last two procedures has its values and its shortcomings. The first has the virtue that all techniques have, in themselves, very wide applicability and also they may serve as the bases for the development of more specialized design formulas. The second method gives the student a sense of the size and the shape of equipment and of some of the economic considerations, but in the process may require the development of a number of specialized formulas which are not exactly those used by any manufacturer and which in themselves are not of great educational value.

Basic techniques and methods for applying them must be learned by those entering the fields of design. However, the discovery and stating of the problem, the synthesis of possible solutions, and the evaluation of the latter also should be studied. These, taken as a whole, comprise the initial stage of design and are vital to the development of new devices.

Many people assume that in invention or a new design can only result from an unexplained flash of genius. It is certainly true that the one who produced the central idea cannot always say exactly what brought it about. There are, however, all sizes of mental steps. Many simple ideas experienced in everyday life, as well as others occurring on specialized technical problems, though much less startling than great inventions, are similar in character to these larger mental achievements. There are recognizable patterns of thought involved in the solution of such large and small problems, and they can be described with some degree of accuracy. Also, certain procedures, judiciously employed, should enhance the chance of success in creative engineering. The purposes of this study will be to explore some of the types of thinking done and some of the factors related to such creative work. Suggestions of a preliminary nature will be made on how such design ability might be developed. While one may see many interesting possibilities outside the field under discussion, this discussion will be confined primarily to the initial phases of engineering development and design.

III. DESIGN IN RELATION TO THE INDIVIDUAL

A. A Simple Classification of Concepts

Choice between alternatives seems to be the almost incessant occupation of those engaged in science and engineering. It is as if the mind acted as a probability filter or sieve into which new observations came to be accepted or rejected in accordance with whether or not they could be incorporated as data which were consistent with past experience. This does not mean that all past experience is retained without change in the face of new evidence (heaven forbid!), but that the scientifically trained are presumed to take particular pains to keep their accepted experiences in orderly groups, with the elements of each group of "facts" consistently interrelated. In an effort to state this somewhat more concisely, Table I was prepared with some examples taken from electrical engineering and applied mechanics:

Table I - A Classification of Concepts in the Physical Sciences and Engineering*

1. Time.
2. Elemental parts or units - such as mass, inductance, force, voltage, velocity, and current.
3. Groups or systems composed of unchanged elements - such as an electrical circuit or a vibratory mechanical system.
4. Relations within each small group between the elemental parts and times - such as the general differential equations which give the voltage drop around each closed circuit, or in a mechanical system which give the sum of the forces applied at each mass.

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* Acknowledgments 1.

5. History and future, or the sequence of events - which might be determined for the above examples under Item 4 were a sufficient number of conditions known at some one instant of time.

6. Relations within larger groups formed from smaller groups - here, it may be found that not only may a larger system be formed from a smaller one, with the elemental parts remaining unchanged, but that it may be better to think of new subdivisions within the whole which are not necessarily identical with the original groups or systems from which the large system was formed. Thus, if two single circuits are joined through an ideal coupling transformer it may be desirable to replace the transformer by a single inductive coupling and to obtain the two new resulting circuit loops.

B. Steps in the Development of an Engineering Product

We need now to establish our assumptions concerning (1) the purposes of design, (2) the usual steps which are taken in carrying through a project, and (3) the style of thinking required.

The work done on new designs (or new organizational developments in engineering) is not done to gain knowledge for its own sake, but to produce something which will be used.

In present day engineering, work on new equipment is usually done by research and design teams in which there are various specialists to furnish aid and support to one another, yet the "Unit" producing a single idea is one human mind. Thus, the individual to be effective must be able in his own right, but, at the same time, have a rather good idea of where his efforts fit into the whole project. We shall look at the work of invention and design from the point of view of a single individual, but assume that he is working as one of a group.

The factors related to the production of a new and successful design are the recognition of a need, invention and design, production, and sales at a profit. The steps involved are outlined below, with emphasis placed on the initial stages of the work.

Table II - Details Which May Be Involved in a Complete Engineering Design Problem

1. The Human Part of the Problem
   (a) The recognition or discovery of a human need or want, real or potential, which might be satisfied through the application of the principles of the physical sciences.
   (b) A statement of the physical result, or results, which it is believed will satisfy the need. This may take one of several forms such as those shown below:
      (i) A single physical result.
      (ii) A single group of results, no one of which excludes the existence of another (even though practical methods of achievement are unknown).

(iii) Several possible results, or groups of results, with a sort of grading procedure established. Such a grading system might involve a minimum performance for each possible result. Then a sort of figure of merit would be needed so that those potential solutions which might meet all minimal requirements, could be compared and ranked according to their order of relative value. This kind of grading procedure (if it could be agreed upon) might permit a comparison of the possible physical systems for achieving results not only after the fairly complete development of each, but at various stages along the way. Conceivably it could be used to cast out or stop investigation upon some system under study so that greater effort could be placed upon the more promising systems.

In any of the above it is assumed that cost in dollars, date of completion, etc., are likely to be included as necessary requirements upon the results to be obtained.

2. The Physical or Engineering Part of the Problem
    - (a) Probably a restatement of the problem in more exact terms. This may involve mathematical relations.
    - (b) The discovery or invention of possible physical systems which it is believed may prove to be satisfactory.
    - (c) A clarification of each system which seems to warrant development.
        - (i) Statement of the assumptions which usually means slightly "simplifying" the problem or, in reality, defining another problem that is believed to be sufficiently close to the actual one to give results which will also be close to the actual. (Often the problem first is "simplified" beyond this, with the idea of starting through again and again later with additional factors included each time as more experience is gained).
        - (ii) Development of a procedure for the analysis and then its employment. This may involve both tests and calculations, and require in some cases the discovery through tests of new physical facts either general or else limited by the specific conditions of the problem at hand.
        - (iii) Tabulation and interpretation of results.
        - (iv) A pondering of these results and their interpretation in terms of the desired results, and of any new evidence or limitations which have come into view, or of any revisions in the desired results which may have occurred since the start of the work.

3. The Judgment of the Engineering Solutions in Terms of the Human Needs.

    Making a choice of one or more of the engineering solutions under Item 2 which may best meet all the requirements coming from 1(a) and 1(b) above.

4. The Detailed Design and Construction
   This statement seems self-explanatory. Detailed designs are prepared and construction undertaken either on a pilot model basis or for full scale development, or both but in sequence.

Many times an engineer is working on only one phase of a large project which actually involves something of each of the main parts listed above, but it is still well for him to know where his work fits into the whole.

C. What is Needed for the Solution of Engineering Problems

Solutions to engineering problems come from human minds, not from machines, laboratory equipment, and calculating techniques. The latter are to provide data and support for the designer's imagination and judgment. Table III is concerned with the mental "equipment" required.

Table III - Mental Abilities Involved in Problem Solution

1. Observation and discrimination.
2. Memory.
3. Logical thinking - with emphasis upon mathematical analysis, other forms of mathematical work or analogous types of effort.
4. Imagination - with emphasis upon the combinations of material things and of symbols to represent them.
5. Judgment - with emphasis upon
   (a) Interpreting observations and discriminations.
   (b) Guiding the imagination (conscious or intuitive).
   (c) Making final decisions when all the available facts are assembled.

These are most, if not all, of the mental abilities of the mind, but qualified by the very narrowing affects of the emphases indicated.

Only brief, further mention will be made of Items 1 through 3 as separate entities.

Observation and discrimination are vital attributes in all laboratory sciences. They are abilities which are all understood, and excellent training is given for their development.

Memory is an ability to use with some care in design work. There are the matters of the long- and, the apparently, short-time retention to consider. Long-time memory should be used to retain basic principles, to say where to find details, and to advise who is known to be an expert in one's own and also in related fields of study. Facts, figures, formulas, integral tables, etc., are all in the books and need not be carried in the head. Short-time memory is another matter.* When engrossed in a problem, one must retain a surprisingly large amount of information for ready use at any one time in order to permit the proper play of imagination and judgment. Here analogies and other tricks of simplification can be of great value.

Logical thinking is so thoroughly and extensively treated in every course in the physical sciences, mathematics, and engineering that it seems almost unnecessary to remark upon it. If there are matters worthy of further mention they are:

(1) that engineers sometimes do not write down their assumptions in clear one, two, three style;
(2) that for clarity they could often afford to break a report up more sharply into the four parts shown in Table II under Part 2(c), and
(3) that they could always get both the assumptions and the conclusions together in one place and in short and concise form which others can easily understand.

IV. THE NATURE OF IMAGINATION AND JUDGMENT

Imagination and judgment seem inseparable in relation to invention and design and will be discussed here jointly and intermittently throughout what is to follow.

Creative design and invention require the knowledge of science but the spirit of art. Some inventors have felt that to achieve in design, one must become attuned to nature in order to project forward in time as does the painter who sees the form and color of the finished work in oil, or the musician who hears and feels the new passages of a yet unwritten theme, or the sculptor who can envision a finished statue in a block of marble, or the inventor who may see the fit of airfoils to the air stream like wings in the wind. Sikorski speaks of intuition in invention as the "forerunner of knowledge" which tells of the correctness of things which later may be proven by observation and analysis.** Yet all of this stems from imagination, a series of forms, colors, sounds, or images which occur in the mind, and intuition is the sense of rightness which says, "Stop, this is it, the meaningful whole." And you stop to see if it really is true.

If this is what we seek, what may be done about so sprightly a thing?

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* Probably any facts which are used for a reasonable length of time are recoverable if a sufficient number of hints are offered at a time when extraneous subject material is excluded from the mind. However, for most practical purposes, that which is used intensively, for a few hours or days or weeks and not likely to be needed again, is relegated here to the short-time classification. After use, it should go into "dead-storage" in order not to clutter up the more needed areas.

** Bibl. Ref. 5, pp. 3 and 4.

It is well to remove, if it exists, a common feeling that "mute, unconscious intuition is emotional, not intellectual and scientific, and therefore, not to be desired."* Danger may exist of "rationalization," true, but this may be tested later by the sterner processes of logic or of the laboratory.

Also, it might be noted that scientific logic is often only quantitatively exact about slightly unreal situations, while imagination (and intuition) may be qualitatively correct regarding more involved problems.**

Next let us consider the inferences made in everyday life. They seem to be simple acts of imagination and of intuition. It would be difficult to say how you recognize the sound of one person's feet; or, how else you can distinguish one person from many others, be it only by hearing one spoken word or by seeing the creases in his shoe. For motoring at night down strange roads which bear no formal signs, one learns to predict with speed and accuracy the turns, hills and valleys. In the main, the inferences made in such matters turn out to be correct conclusions. They seem to be arrived at intuitively from insufficient data, but can it be insufficient when the results are so often true? Sometimes at a later date we believe that we can deduce from what and how the intuitive conclusions were drawn. It is highly improbable that intuition in these cases is a persistent-arriving-at-right-answers from wrong premises and by illogical routes. Is not intuition similar to reason but not active at the conscious level?*** In the one we can write it all down, in the other we cannot or do not do so, but probably the steps are essentially the same. Thus we see the laborious proof of correctness arrived at by conscious logic in contrast with the possible flash of probable correctness (intuitive judgment). There seems to be a plodding stolidness about the steps of logic as compared with the rushing about through space and time which the imagination will do in preparation for intuitive action. In the one, the steps are sure and slow; in the other, more tentative but more rapid. This must be taken into account, and will be returned to later, as it has a bearing on one's training and practice.

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* Bibl. Ref. 15, p. 20.

** Since much of the logic of science presumes one set of causes to produce one and only one set of effects, much mathematical analysis has been impounded for machines to do, so at times analysis may become quite literally a tool. But imagination, not machines, developed the original mathematical relations and also the machines to represent them. As contrasted with the mathematical symbolism written out on a plane surface, these machines may be thought of as specialized systems of symbolism in three dimensions. They can be arranged to accept the truths put in and to bring out these truths rearranged in those new forms which we call the "answers."

*** Perhaps it would be more satisfactory to define intuition as a combination of reason and judgment based upon unrecognized or subliminal cues.

Apparently we can develop the ability to think in many kinds of imagery and try various combinations for rightness, and also it seems apparent that this process can proceed at times without conscious effort, yet come to correct conclusions. Therefore, should we not consider how we may consciously develop the art of imagery and with what conditions we may surround ourselves to favor the intuitive process in order to arrive at probably correct conclusions? We shall endeavor to do this, but first one brief word regarding the practical.

There is a vast difference between the "crack-pot inventor" and the designer of successful new devices. Each must have developed that knack of arranging in the imagination the new and novel, but the difference is measured not by the degree of newness found in the ideas, but by the judgment with which they are weighed. Questions must be asked and answered. Why is this job worth doing? Is the magnitude of the improvement likely to be such that it will be unquestionably accepted, or is it apt to be only of a marginal sort at best? What will it require in men's time, in money and in materials? Is there something else which should take precedence? Yet the necessary appraisals should not be allowed to dampen the ardor for achievement.

V. IMAGINATION AND JUDGMENT IN INITIAL DESIGN

A. Aids for Imagination and Judgment

A person may be seeking a need for a product or a product for a need. Thus at one time new uses were actively sought for both artificial rubber and for spun glass while, during the early days of World War II German developments on the magnetic mine made many degaussing designs mandatory.

The discovery of the human need to be followed by an engineering solution is the sequence which will be assumed below. In such work there are needed (1) a storehouse of knowledge arranged to suit the designer's way of work, (2) an initial statement of the problem at least in general terms (and, if general, to be made specific as rapidly as developments permit), (3) a "soaking-in process," wherein the designer seeks to encompass within his ken an array of facts and possibilities related to his purpose and to try various combinations of these, and wherein the designer makes a gradually increasing use of the technical literature for support, (4) a final careful restatement of the problem and of the proposed solution with the attendant evaluations.

B. The Storehouse - Human Needs

The storehouse must contain in a reasonably orderly fashion "facts" and "hunches." Of course these "hunches" or conjectures must be carefully tagged, but they should be given an appropriate tentative status. This knowledge and these other ideas should relate to human needs as well as to physical relations.

There will be a trend toward orderliness and hence availability of ideas on human needs, if they are put away in accordance with some system. Such ideas might be classified according to existing products or, perhaps, in terms of some more elemental list such as that outlined below:

Table IV - One Possible Classification of Human Needs

1. Preservation of one s own life and to a lesser extent health, are ever present needs. Weapons were developed early. Today a widening and deepening of the air lanes as well as automatic blind landing systems seem necessary to make safe the coming volume of air traffic.

2. Savings in economic values as defined by money, man hours and materials account for most, though not all, engineering developments. Perhaps far too many of us have held closely to the strictly engineering uses for designs. There has been much opportunity and should be more in satisfying the needs of the home, of agriculture, of merchandising and of medicine. Possibly new and less costly medical and office equipment for those doctors engaged in group practice might be as well received as would be a new totally-enclosed motor for use in a chemical plant.

3. Individual freedom of action. We like to talk. We want to be able to talk to any place in the world. We are going to enjoy more and more seeing distant places displayed on the television screen. Most of us would enjoy even greater opportunities for travel than we now have. What can be done to further satisfy these desires and what other freedoms of action are there which need the support of engineering invention?

4. Comforts in terms of any of the senses have been the wants upon which immense industries were built, yet each year we endure much heat, cold, drouth, dampness, blinding light, disturbing darkness, unpleasant odors, smoke, dirt, and wearing noises. Means for the further reduction of some of these annoyances might be justified to the user, not only on the basis of comfort but also of direct economic gains.

5. Amusements and escape from the daily requirements of life only need mentioning to bring to mind hosts of growing industries.

6. Release from drudgery. Engineers have applied much thought to home, farm and factory equipment, yet in the factory and in the office efficiency has so often been measured primarily by the stop-watch, the time card, or else the number of square feet of paper turned out by typists and draftsmen. To some extent these may serve as measures and thereby as incentives. Yet there must be millions upon millions of human beings who would rise to greater levels of productivity if their work were made

more interesting and more stimulating. The designers as well as the management engineers who venture into this field may expect to meet vested interests in both labor and management. Prejudices, and organizational problems as well as knotty design problems are in store, but there is a great deal of work to be done. Economic gains in both intangibles and tangibles must be clearly shown. This is no place for the timid.

7. Worry, anxiety, and fear appear from time to time as unwelcome visitors in every home and in every human heart. Job security, adequate medical care, and educational advantages for their children are of paramount importance to most parents of only moderate means. Can the engineer do something toward "leveling out" employment, help to make medical care less expensive, or to improve educational procedures? It is no secret among engineers that they are particularly prone to criticize the instruction given their own children in mathematics and physics at the high school level and to some extent that given in languages as well, but who does anything about these? Are there not potential visual aids in all of these fields which could be designed in cooperation with high school teachers and sold throughout the country?

C. The Storehouse - Working Tools

We have talked of human needs. Next we should see what the designer's storehouse should hold in that large part allotted to physical things.

Ideas are needed on the properties and the potential uses of materials. Thus, we like to know if they corrode easily, change resistance with temperature, obey Hooke's law, if they are electrical insulators or conductors, if they shrink with age, and if they are brittle or pliable. Besides such general ideas, where should we look and to whom should we go for the detailed and very unusual facts? Also, we might well carry around a few ideas on what groups of properties we would like but have never seen in any single material. It does not pay today to sell short the chemists or the metallurgists. If they don't have it yet, it may be on the way or even developed now by modifying some existing synthetics or alloys.

Electromechanical designs so often involve in their makeup gears, cams, linkages, ratchets, Geneva movements, etc. The designer should embrace certain ideas regarding:

1. Possible types of motion.
2. Ways of producing one motion from another.
3. Methods of representing in various fashions certain operations such as addition, subtraction, multiplication, and integration.

Some things worth knowing about electrical circuits are:

1. How to get from one voltage to another in both alternating and direct current circuits.
2. How to get one type of variation in electrical quantities to produce another.
3. How to represent the mathematical operations mentioned above, including differentiation.
4. The performance characteristics of motors and other transducers.

Too few electrical and mechanical designers are well versed in geometric optics and in photography. These are of particular value in measurement and test. A designer needs to know that choice can be made between mechanical, electrical, and optical devices, particularly in dynamic problems, on the basis of accuracy as well as weight, size, convenience, and cost. The elimination of one method in favor of another usually can be done early if the requirements and preferences have been clearly written down.

One of the past great designers in electrical engineering, Mr. B. G. Lamme, is reported to have advised, "Watch the man who thinks in analogies." As one mathematical expression may represent a variety of physical situations, much work has been done to classify the analogous parameters and variables in electrical, mechanical and acoustical vibrating systems.* If one thinks rapidly and fluently in one system but not in another, he may establish the analogy in his own language and proceed with the expectation that he can translate back again later on. This is all right for qualitative work, because rigorous procedures probably can be introduced later for calculations on the original system if there are some "extenuating circumstances." Electrical types of computing machines have been developed for the study of dynamic systems, making use of the known analogies, and of the extreme ease with which electrical parameters may be changed, and with which the variables may be displayed on meters and oscilloscopes.

D. The Statement of the Problem

Thus far we have been considering the arrangement in the mental storehouse of the tools of design. The "soaking-in" process is where we try to use them, but first the desired physical results must be defined, at least in general terms, before we can imagine what can be done about achieving them.

The statement may seem strange, but often times a person starts without knowing just what he wants to do. Sometimes you just "do not like the way the thing is being done," and at other times you feel "there must be something missing here." These responses are perfectly natural. However, to avoid meaningless daydreaming it is necessary to get the desired result stated as quickly as possible, if only in general terms. What are you trying to improve and why, or what is missing? The first definition of result does not need to be so well refined that it could be given out immediately to someone else as a problem, but if not then, as one starts to think of the ways and means and to marshal all relevant knowledge, he should continue to define and to redefine the results desired until they stand as sharply as beacons in the night.

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* Bibl. Ref. 19 through 24.

If a man can state concisely what belongs under each of the three headings shown below, he will have gone a very long way toward defining the problem:*

1. To produce (if it is a design problem:--------
   or to determine (if it is an analysis or test job):
   ----
2. To overcome the specific obstacles of:--------
3. In such a way as to attain the specific aims of:--------

E. The Soaking in Process

In his imagination a small child makes himself the central figure in a story and enjoys the excitement of the terrific situations which he creates. A designer should dream for a purpose -- one purpose -- to obtain the result he has defined. Nevertheless, he needs at first to have a free running imagination which is working smoothly at many periods of the day in order to fit together various images which may achieve his goal. Quite frequently no good solution is found before he has touched, even though lightly at times, upon almost everything which conceivably might be employed. Since a new idea usually means a new combination of known information the job is to increase the likelihood of the right combination appearing and of being recognized as the desired "meaningful whole." Since you don't know what it is going to be, this is a matter of trying to shade the probability in your favor.

Systematizing may help. Thus the selection of the most likely fields or areas in which to work and the elimination of others may be first steps, yet some consideration of the bizarre may also yield results. If something has always been done one way, you might consider briefly at times what would happen if you did it in the reverse or in some other order.

You cannot build up a very intricate idea or keep from repeating yourself without the use of visual aids. Some sort of shorthand techniques are needed which do not hold you back or distract you from your main ideas. Block diagram procedures are good. One may have two input quantities, one of which controls the other to lead to a certain output. The radio engineer draws a square with an "A" in it to designate an amplifier and then shows by lines the inputs and the output. Gearing may be similarly represented, and so may a hydraulic valve. Flow may be unilateral or bilateral and indicated by arrows, or not, as seems desirable. (This style of thinking is not limited to engineering devices.) When needed, vectors should be freely used. At times one may care to invent symbols for which he knows of no simple standard types, such as for gearing, bearings, friction elements, mass, shafts, etc.

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* Acknowledgment 2.

Ability at free hand perspective drawing is an art well worth developing. Paper may be secured with guide lines for perspective and also for isometric drawing. Either of these may be useful to the less well trained at sketching.

When you feel that ideas may be sufficiently well formed, try writing them down with brief diagrams, drawings, symbols, etc., as needed, but with no delay set in through the normal requirements of grammar and of completeness in mathematical work. Just get enough down to sketch out the whole or a large part of the job. Thus, any good sequences of ideas are caught at a time when they were fresh in your mind and errors and omissions in the overall plan are likely to be quickly exposed.

It is well to remember that nothing is much faster than conversation for the exchange and correction of ideas. You can cover ground so much faster in a qualitative way by this procedure than you can either by reading or by writing or both. People who will listen to you and discuss your problem can be of invaluable assistance. The mere act of explaining out loud assisted, perhaps, by brief sketches on a blackboard or on paper will force the marshalling of thoughts and will tend to show up weaknesses.

If the device contains moving mechanical parts, a rough wooden model (possibly metal, if gearing is involved) can be of immense help for getting satisfactory proportions and for indicating needed checks on clearances, etc. Usually the model does not need to be a polished job. For instance a nail may serve for a bearing or afford limited flexibility between parts.

Thus far we have dealt with knowledge and techniques. There are certain other factors which are related more to personal habits and behavior.

If the designer expects to have new ideas it is a fairly good rule to try to lay the groundwork before mid-afternoon. Of course there are some most outstanding exceptions to this idea, but it seems to be accepted as generally sound. Sometimes you have to pretty much live in the job day in and day out and if this is not possible, then at as many spare periods of time as can be found. This means enthusiasm for hard work and lots of it.

Eventually such continuous striving, if carried on without much success, will lead to great frustration and discouragement. Some have thought this to be a part of the productive process, since it may drive the mind to results. However, I think that usually extreme frustration is only the result of the common, but not necessarily good habit of hanging on beyond the reasonable limits of endurance. It is often incident to, but not necessary for getting results. Certainly if the feeling of frustration and dissatisfaction gets bad enough, it will force a man to seek release in other activities. The rest, change and return to the problem from a distance are likely to turn the trick of finding the answer consciously or unconsciously. (One seems only to read about the cases where the idea comes in without being sought, but this is, of course, the more spectacular sort of entrance for an idea to make, and hence we should expect to hear more of it.) It is most likely that a good deal of wear and tear can be saved by deliberately changing the scene before one gets into such a state of fatigue. Hobbies, a trip to the mountains or lakes, or music may get one away at the right time, and perspective may be gained upon return.

Nothing has been said thus far about the use of books, technical papers, reports or other aids which go under the name of bibliographical material. Certainly the problem should be pretty clearly stated before any reading is undertaken. How soon thereafter one should start reading is very hard to say. If you start early you may save time, and also you may keep yourself from hitting on anything new. If you wait until you have written down on paper your first rush of ideas, you increase the "hit expectancy" of a new idea, but almost certainly you will also shoot up a lot of "dead ducks" that others have laid to rest long ago. Nevertheless, there are a good many cases where you should delay the careful library search for several days while the salient possibilities which are likely to occur to you have come to mind.

F. The Final Statement of the Problem and of the Proposed Solution

Finally, when the plan is sketched out and looks sound, the designer must change from the imaginative thinking in qualitative terms to the analytical work in quantitative terms. The object or desired result must be very carefully restated and the usual sort of rigorous calculations, tests, and reports on the design must be worked out. Limitations, advantages, and disadvantages of the plans must be sought and weighed as dispassionately as if they were being proposed by someone else. This is the frame of mind to be sought for at this last stage in the design. The difference between this and the imaginative phase cannot be overemphasized, yet ability and control are needed by the successful designer for each of these phases of the work.

With the statement of the proposed solution should go an evaluation of the proposed product. Two kinds of evaluation are desirable, one by experts (engineers and scientists) who may perceive the technical possibilities of failure and the other by representative users as they are more likely to see the probable operating inconveniences. Many large companies make systematic inquiries among critics of both types.

We have come about to the point where the final design is undertaken, and thus we have covered, as I see it, the initial stages of design which it was our purpose to accomplish. There is room - in fact, there is an expanding space for those who are interested and who may become qualified, for the initiation and design of new devices and machines. It is a challenging field for those who wish to work in it and one worthy of appreciation by all.

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Acknowledgements:

(1) With some modifications and adjustments, Table I grew out of an idea presented by R. H. Seashore, Chairman, Department of Psychology, Northwestern University.

(2) Also I am directly indebted to R. H. Seashore for the particular form employed for the statement of a problem, which reads "to produce, to determine, etc."

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